Industrial QUALITY CONTROL

Vol. XIII, No. 11
MAY, 1957

Welcome to Detroit

Eleventh Annual ASQC Convention and Exhibition

QUALITY through Scientific Methods

Journal of the
AMERICAN SOCIETY FOR QUALITY CONTROL

DoALL Sets New Industry Standards for Gage Blocks...and Reduces Prices

COMPARISON OF DoALL GAGE BLOCK STANDARDS
WITH NATIONAL BUREAU OF STANDARDS CRITERIA AS OF FEB. 1, 1957.

GRADE		LENGTH		FLATNESS		PARALLELISM		SURFACE FINISH		HARDNESS		GENERAL COMMENTS
DoALL	BUREAU	DoALL	BUREAU	DoALL	BUREAU	DoALL	BUREAU	DoALL	BUREAU	DoALL	BUREAU	
AAA	None	+.000001" −.000001"	None	.000001"	None	.000001"	None	0 to 0.09 AA	None	66 Rc	None	Finest blocks manufactured commercially
AA	AA	+.000002" −.000002"	+.000002" −.000002"	.000002"	.000002"	.000002"	.000002"	0 to 0.09 AA	0.5 AA	66 Rc	65 Rc	Most accurately calibrated AA Blocks available
A+	None	+.000004" −.000002"	None	.000004"	None	.000004"	None	0 to 0.09 AA	None	66 Rc	None	A+ Grade for the price of B
A	A	+.000006" −.000002"	+.000006" −.000002"	.000004"	.000004"	.000004"	.000004"	.8 AA	.8 AA	65 Rc	65 Rc	New low priced "working" SHOP-BLOCKS
None	B	None	+.000010" −.000006"	None	.000006"	None	.000006"	None	1.2 AA	None	65 Rc	Not recommended for today's tolerances

Every DoALL Gage Block is unconditionally guaranteed to meet DoALL specifications for its grade as shown above.

Here is What Has Been Done:

- **B Grade blocks discontinued** *on the basis of their inadequacy for controlling modern tolerances.*
- **New AAA Grade (± .000001")** *established for ultra-precision control.*
- **AA Grade (± .000002")** *reduced in price as much as 70%, permitting wide usage for routine inspection work.*
- **New A+ Grade (+ .000004", 000002")** *established for inspection and shop use, and offered at B grade prices.*
- **New optical surface finish** *of 0 to 0.09 arithmetical average for AAA, AA and A+ blocks, permitting more accurate calibration and lengthening block life.*
- **New A Grade "working" SHOP-BLOCKS** *established and offered at B grade "working" block prices!*

Better Blocks for Better Control

Completely new gage block standards have been established by The DoALL Company after a comprehensive appraisal of modern measurement needs.

With .001" a common tolerance today, B grade blocks no longer provide adequate dimensional control of working gages in the *shop*. And when parts tolerances of 100, 75, 50 and 25 millionths are specified, the need for blocks of greater accuracy becomes apparent immediately.

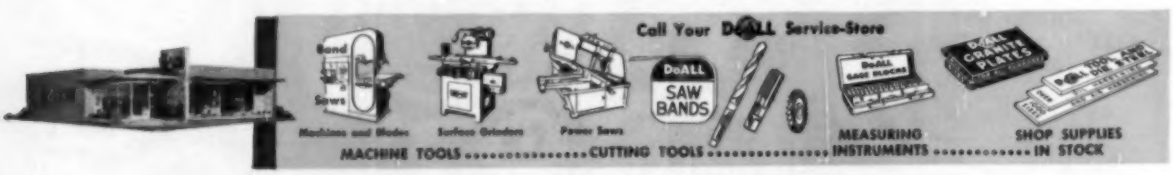
To meet these conditions . . . to reduce costs, rejects and waste . . . DoALL has upgraded its entire gage block line as shown at the left and in the table above. At the same time new manufacturing techniques and increased production have made possible major price reductions. For example, you get *A+ grade blocks for the price of B.*

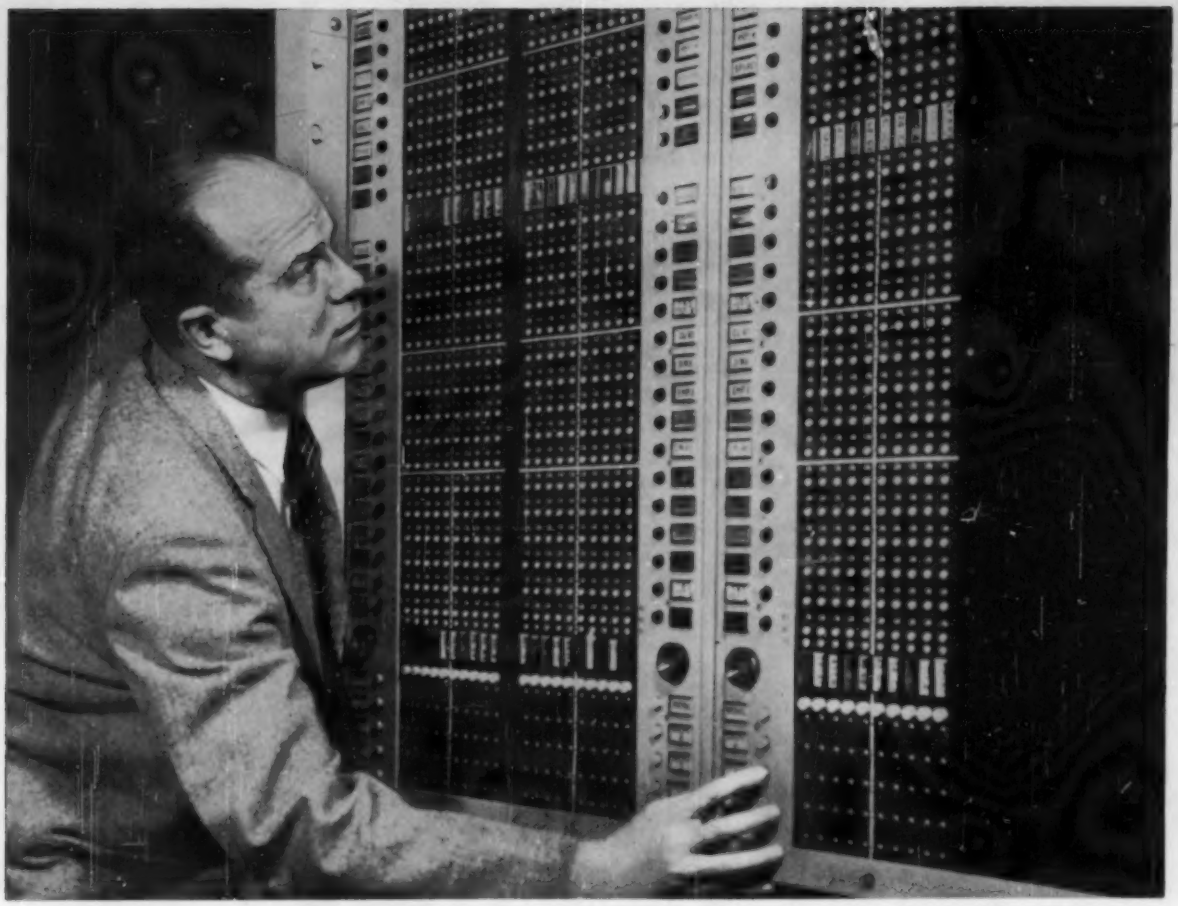
Note that B grade blocks have been completely discontinued. Even the new DoALL SHOP-BLOCKS are A grade . . . available at the price of B "working" blocks.

DoAll now offers you the most accurate line of gage blocks in the world. They provide finer, lower cost dimensional quality control than has ever before been available. Why not take advantage of it . . . at no premium in price. Call DoALL locally or write today.

ASK FOR LITERATURE

THE DoALL COMPANY
Des Plaines, Illinois





Bell Laboratories engineer Cyril A. Collins, B.S. in E.E., University of Washington, demonstrates new TV switching control panel for black and white or color. Complex switching connections are set up in advance; in a split-second a master button speeds dozens of programs to their destinations all over the nation. Special constant-impedance technique permits interconnection of any number of broadband circuits without picture impairment.

Telephone science speeds TV enjoyment

Telephone science plays a crucial part in your TV entertainment. An interesting example—one of many—is the latest TV switching center developed at Bell Telephone Laboratories.

Switching centers control the transmission of programs which come to your local TV station over Bell System facilities. To be available exactly on cue, programs must be switched at high speed and with very great accuracy.

To create the new switching center Bell Laboratories engineers borrowed from the switching control art which handles your dial telephone calls. They developed a special control panel which puts complex switching patterns within the easy grasp of one man. By pushing buttons, he sets up—and double-checks—forthcoming network changes far ahead of time. On cue he presses a master button which sends the programs racing to their respective destinations around the nation.

To connect the broadband circuits, the Laboratories engineers developed a new video switch which operates on a constant-impedance principle. The new switch permits the interconnection of any number of circuits, without the slightest impairment of transmission quality.

Thus the technology which serves your telephone also works for your TV enjoyment.

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Quality Control

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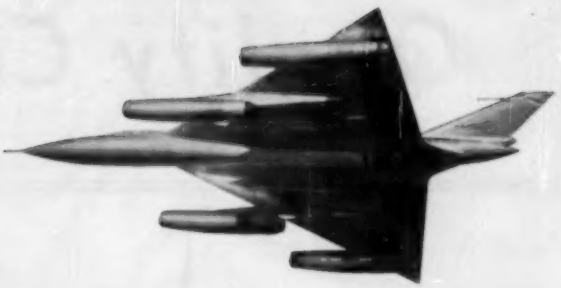

MORE AND MORE
MAJOR COMPONENTS
ARE BUILT BY ROHR

For example, brazed, stainless steel, honeycomb panel structures are being manufactured by Rohr for the great new B-58 Hustler, built by Convair for the U. S. Air Force.

Today Rohr manufactures over 30,000 airplane parts, included in such major components as stabilizers, elevators, fuselage sections, pneumatic system components, high strength weldments, and stainless steel honeycomb sandwich panels.

More and more, leading air-frame manufacturers count on Rohr for design engineering, for conception, development and production of parts to meet modern flight problems. In many cases, Rohr engineering teams are actually assigned to the customer's plant, to work with the manufacturer's engineering staff and bring back a full understanding of requirements to be met.

And, of course, Rohr is well known as the world leader in production of ready-to-install power packages for airplanes – including the Boeing B-52, KC-135, 707, Convair 880, Lockheed Electra Propjet, Super Constellation, C-130, Douglas DC-7 – and many other of America's leading military and commercial planes.

For the aircraft parts you need, next time look to Rohr.

WORLD'S LARGEST PRODUCER OF READY-TO-INSTALL POWER PACKAGES FOR AIRPLANES

Excellent career openings now for engineers and tooling technicians.

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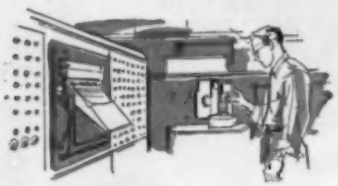
Also plants in Riverside, California • Winder, Georgia • Auburn, Washington

Quality Control...

You can see it Best at Alcoa in terms of a single Aluminum Forging

As far back as the melting pot at Alcoa's Massena, New York, plant, quality control was at work on this forging. Quantometers analyzed the melt in minutes to make sure the ingot, as poured, would be on the nose.

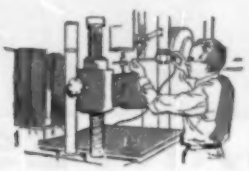


When the ingot cooled, a sample slice was taken from it, polished and etched. A powerful microscope laid bare its grain structure.

Then the ingot was rolled into a bloom—worked into finished forging stock. Ultrasonic inspection at this point combed the finished stock for hidden flaws with high-frequency sound.

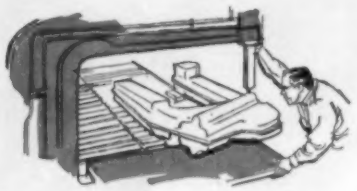
On to the blocking dies at Alcoa's Cleveland forge shop. After the first 50,000-ton squeeze, the rough forging was cleaned and etched. Trained eyes scanned its surface for minor flaws and breaks. Ultrasonic instruments probed its innards for cold shuts and tiny defects.

Next the finishing dies. Now the finished forging underwent another ultrasonic inspection, etching and surface scrutiny. A test section was cut from it and tested for tensile, yield, elongation and creep. Destructive testing it's called.



Other sections, from areas of greatest strain, were polished and etched. Forging experts checked these under microscope to make sure the tough, fibrous grain structure was properly aligned for ultimate strength.

Now for heat treatment. Separately forged test bars from the same parent metal were heat-treated along with the finished forging. These samples and the finished forging, too, were Brinell tested for specific hardness.



The finished forging moved on to Zyglo inspection where fluorescent dye revealed any minute surface flaws under black light.

All these tools of quality control are employed in every Alcoa forge shop on a rigid, statistical basis.

To the customer, these inspections mean fewer rejects, less wasted machine time, lower costs, avoidance of salvage operations.

To the user, these inspections mean safety and a product he can trust.

To Alcoa, these inspections are a practical definition of quality control.

The sun never sets on International Harvester equipment.

And where you find International equipment, you find International quality control. It is an important part of every one of our manufacturing facilities—foreign and domestic. It is a vital part of the trucks, tractors, farm implements, and construction equipment that rolls off our assembly lines today.

International Harvester believes in quality control. It is one of the reasons why our customers believe in us.

INTERNATIONAL HARVESTER

"The Kimberly-Clark Corporation began in 1914 to look to its Research and Development Laboratories for additional ways of providing quality products at suitable costs. Many scientific techniques such as statistical methods have promoted progress through the years. Only by taking advantage of the contributions of science can an industry expect to meet the constant demands of the customer for higher quality and lower costs."

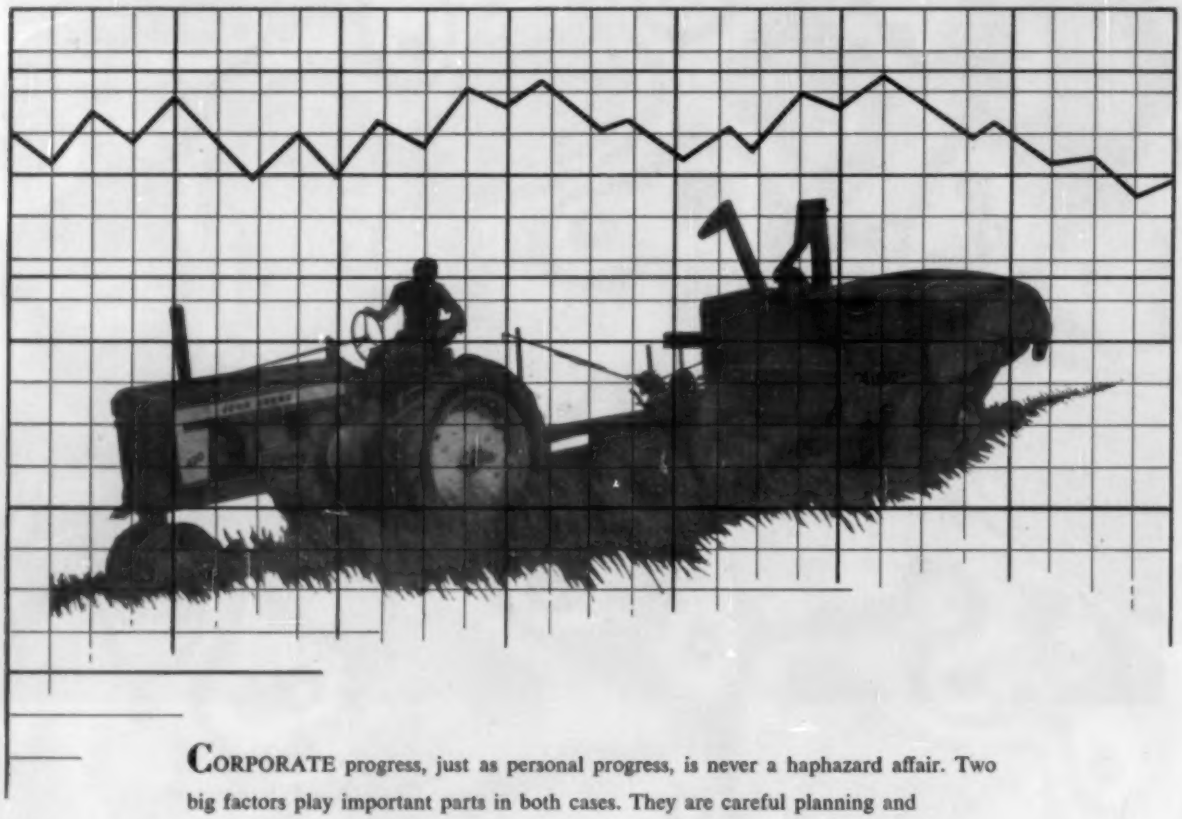
W. H. Swanson

W. H. Swanson
Vice President In Charge of
Research and Development

KIMBERLY-CLARK CORPORATION

NEENAH, WISCONSIN • MANUFACTURERS OF PAPER AND CELLULOSE PRODUCTS

PROGRESS
Always Goes According to Pattern



CORPORATE progress, just as personal progress, is never a haphazard affair. Two big factors play important parts in both cases. They are careful planning and constant vigilance.

Good planning in industry, of course, includes many things and touches upon many phases of the business. Not only must the product be carefully planned, but also its manufacture, including the selection of materials, tools, and production methods.

The second element of industrial progress, constant vigilance, is just as important as the first. This is the "watchman" of the production end of the enterprise, the guardian of quality and efficiency, charged with making sure that there is no serious deviation from the adopted pattern. And at John Deere this is the responsibility of Statistical Quality Control, an integral part of the Company's operations since the inception of the system in 1944.

JOHN DEERE
MOLINE, ILLINOIS

VTOL

...new dimensions of FLIGHT

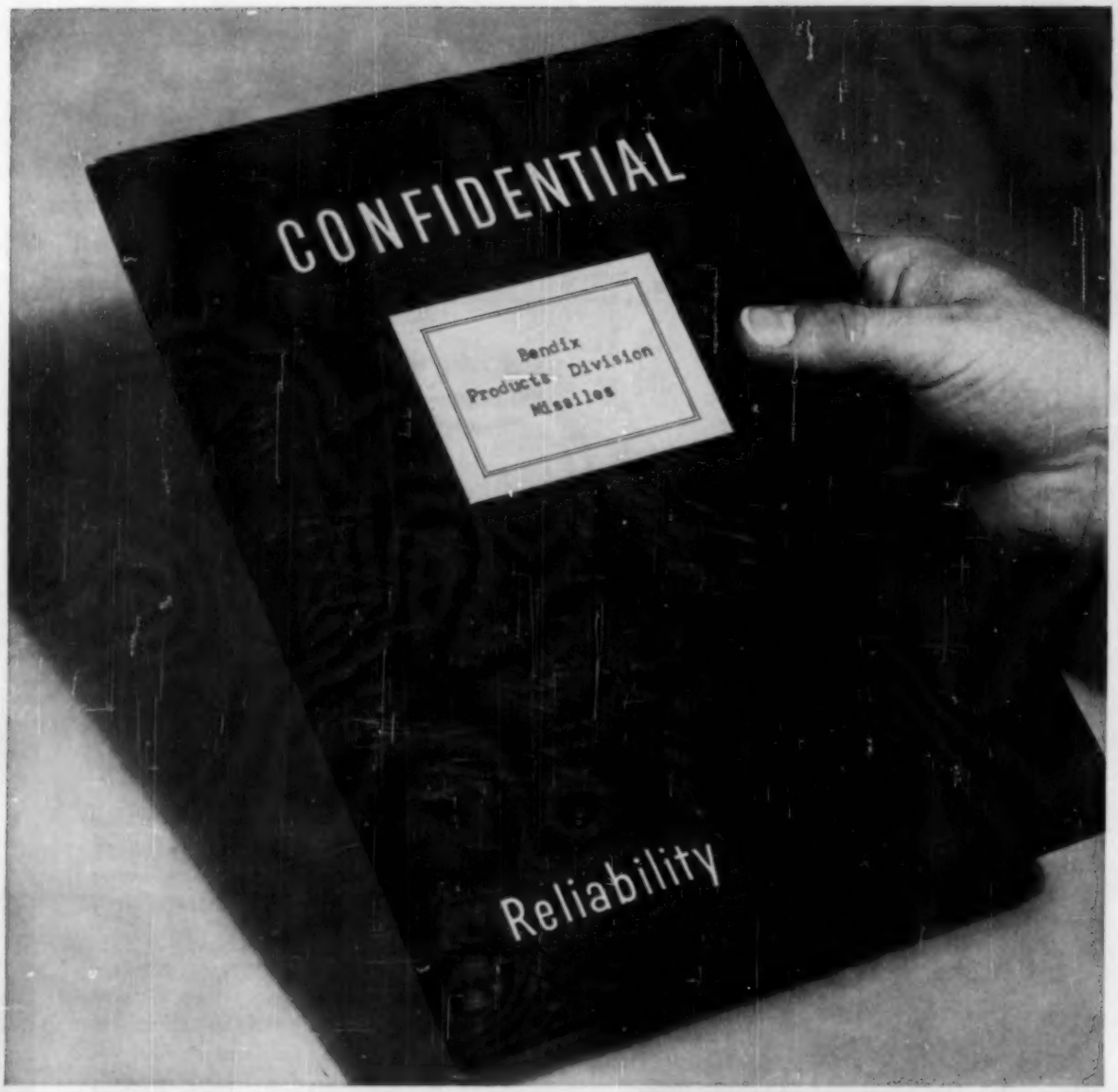
BELL Aircraft Corp
BUFFALO N.Y.

BELL AIRCRAFT has kept pace with the need for greater operational mobility and flexibility in both military and commercial aviation by developing four basic types of VTOL (vertical-take-off-and-landing) aircraft.

Studies and development work on a ducted propeller prototype have advanced to a point where this new design concept is fast approaching reality at Bell. The X-14 uses new principles of jet propulsion to take off and land vertically with the airframe in a normal horizontal position. The XV-3 convertiplane takes off like a helicopter, but as its rotors tip forward in flight, it becomes a normal, fixed wing aircraft. The XH-40 turbine-powered helicopter has substantially increased speed and payload and the ability to use a wide range of fuels.

The skillful and imaginative type of research which was the forerunner of these projects is being carried steadily forward at Bell Aircraft in the interest of still further scientific advancements in the commercial and military aircraft of tomorrow.

RESEARCH, DEVELOPMENT and PRODUCTION IN THE FIELDS OF: Guided Missiles • Research Aircraft • Servomechanisms • Electronics • Rocket Engines • Electronic Control Devices • Vertical Rising Aircraft



A report to the General Manager

The Bendix Reliability Department keeps the General Manager constantly abreast of Talos Missile reliability. Management acts immediately on recommendations based upon facts to build a better and more reliable missile. No effort spared—no stone unturned to attain top reliability.

Excellent Opportunities for Reliability and Quality Control Personnel at

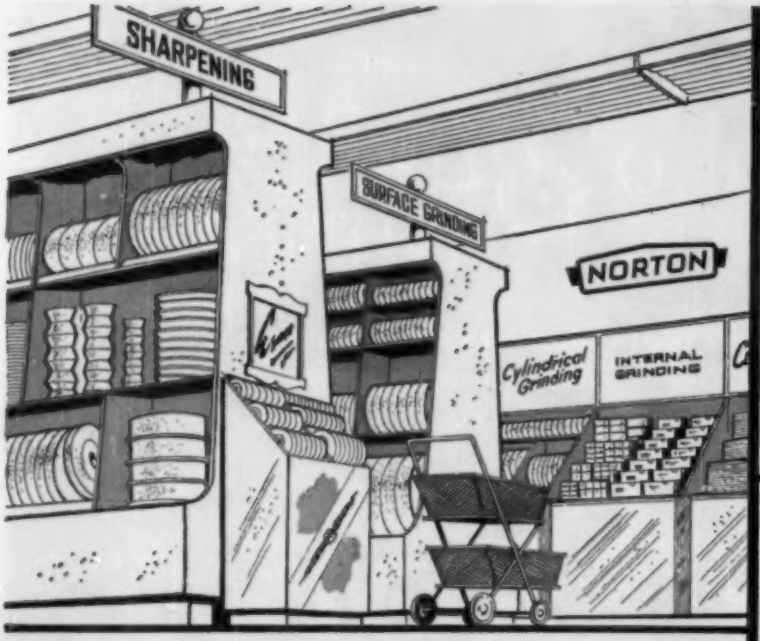
BENDIX PRODUCTS DIVISION—MISSILES
400 SOUTH BEIGER STREET, MISHAWAKA, INDIANA

the control of quality is paramount

our reputation has been built on it
our future depends on it

fibers — Chromspun® and Estron® Acetate, Verel Modified Acrylic
plastics — Tenite® Acetate, Butyrate and Polyethylene
chemicals — For home, industry and agriculture

EASTMAN CHEMICAL PRODUCTS, INC., subsidiary of Eastman Kodak Company, KINGSPORT, TENNESSEE



Here's your SUPER-MARKET for tool room grinding wheels

Norton makes wheels for every tool room job . . . precision-built for "TOUCH of GOLD" uniformity

"Everything under one roof" is the modern super-market advantage you get with Norton wheels — the world's largest line, with exactly the right wheel for every tool room grinding job you do.

Norton wheels are precision processed to duplicate wheel balance and structure with precise uniformity.

To you, this means wheel after wheel and lot after lot will grind alike — with the same time-and-money-saving "Touch of Gold" performance.

And remember: only Norton offers you such long experience in both grinding wheels and grinding machines to help you produce more at lower cost. For aid in wheel selection and helpful booklets on tool room operations, see your Norton Distributor. Distributors in all industrial areas, listed under "Grinding Wheels" in your phone directory, yellow pages. Behr-Manning Company, Troy, N. Y., division of Norton Company. *Export:* Norton Behr-Manning Overseas Incorporated. **For the booklets or other information write to Norton Company, Worcester 6, Massachusetts.**

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Making better products... to make your products better

NORTON PRODUCTS: Abrasives • Grinding Wheels • Grinding Machines • Refractories
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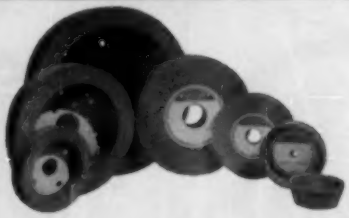
NORTON G BOND AND BE BOND WHEELS bring you the most efficient vitrified bonds ever developed for precision and semi-precision grinding. For sharpening and for surface, cylindrical and internal grinding on all steels and cast alloys use G Bond or BE Bond Wheels in 32 ALUNDUM*, 38 ALUNDUM, 19 ALUNDUM, or the new non-premium priced 44 ALUNDUM abrasive.

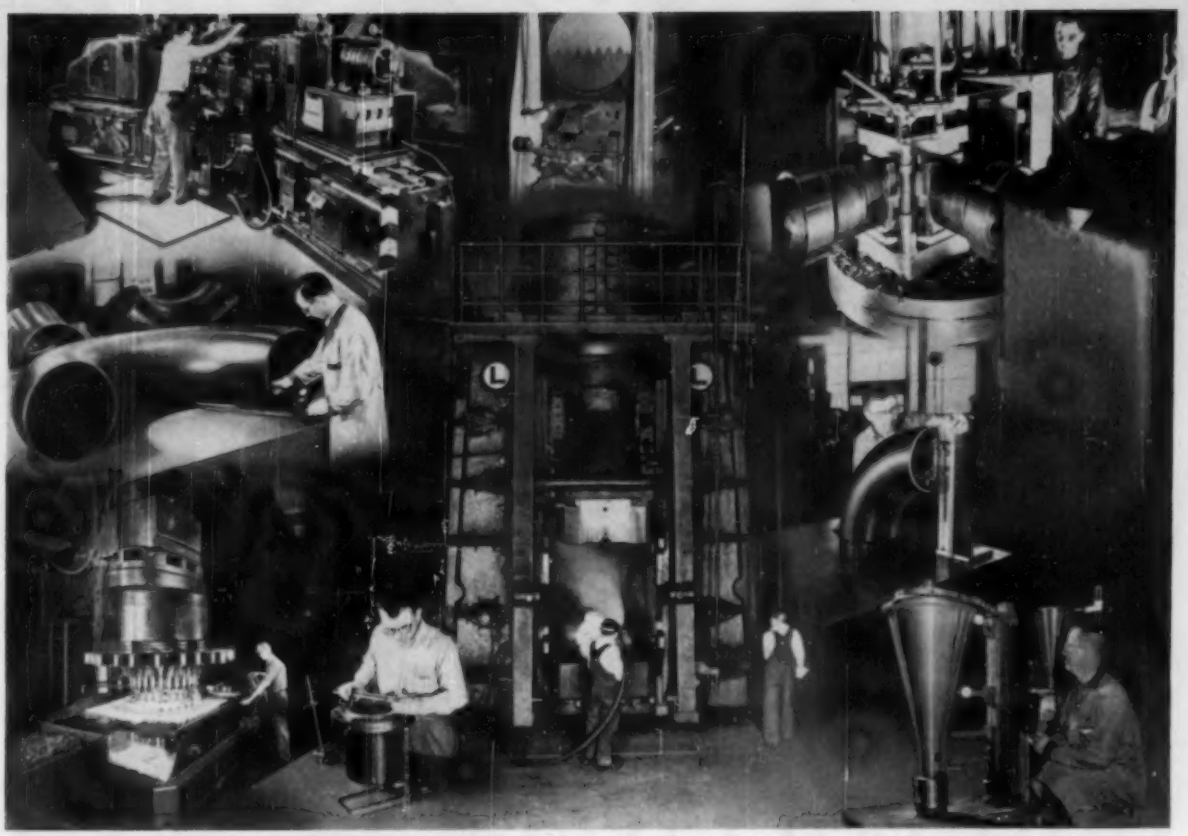
NORTON DIAMOND WHEELS for carbide grinding are backed by long leadership in diamond wheel development and manufacture. The regular B resinoid bond is ideal for wet grinding — the B6 resinoid bond for dry grinding.



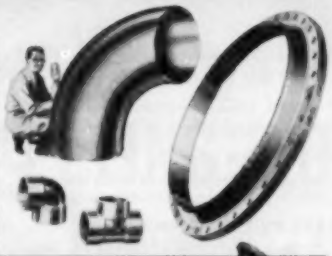
NORTON K BOND WHEELS IN CRYSTOLON* abrasive are often the best investment for many carbide grinding jobs. The vitrified K Bond comes in half-grade increments of hardness, enabling you to "pin-point" your specifications.

BOOKLETS THAT TELL YOU ALL. *A Handbook on Tool Room Grinding* is over 200 pages long and crammed with facts it will help you to know. *How To Select Wheels For Precision Grinding Tool And Constructional Steels* shows the way to correct wheel selection. Get these from your Norton Distributor or write to the nearest District Office of Norton Company, Worcester 6, Massachusetts.

*Trade-Marks Reg. U. S. Pat. Off. and Foreign Countries

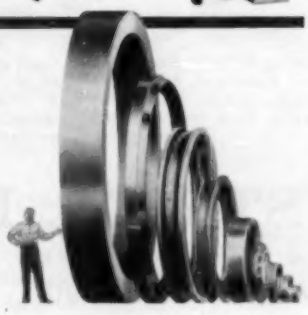


PIPE FITTINGS
Complete line in types, sizes, ratings and material specifications.



DROP FORGINGS
Up to 12,000 pounds in all forgeable material specifications.

ROLLED RINGS
Up to 100,000 pounds, 20 feet diameter. Rectangular and contour cross sections.



STATISTICAL QUALITY CONTROL ASSISTS IN ASSURING PRODUCT UNIFORMITY

Illustrated above are typical manufacturing and inspection operations made more effective by the application of statistical quality control methods.

These methods are used as an important tool in building uniformity, consistent quality, maximum reliability and dependable performance into every Ladish Controlled Quality fitting and forging.

TO MARK PROGRESS

LADISH CO.

CUDAHY (Milwaukee Suburb) Wisconsin

Branch Plants: Ladish Co. of Canada Ltd., Brantford, Ontario
Ladish Co., Tri-Clover Division, Kenosha, Wisconsin
Ladish Pacific Division, Ladish Co., Los Angeles, California
District Offices in principal cities.

QUALITY

...the unseen ingredient in every product by

HOUDAILLE
INDUSTRIES, INC.

● Modern quality control methods, testing equipment and statistical quality controls in every Houdaille plant help maintain the highest product standards. Flutter dampers built for leading airframe manufacturers at Houdaille's Buffalo Hydraulics Division must undergo several days of exhaustive testing on equipment such as this, before they are released to the customer.

You can't always see or feel quality in an industrial product. But you can observe the *effects* of quality in a number of ways. Steadily increasing sales...continued acceptance by customers...attitudes of your suppliers, and of your own production and engineering personnel. And, of course, in basic product performance.

Houdaille's network of manufacturing plants produce thousands of diversified products... from drop forgings to shock absorbers... crushed stone to arbor presses. The one common ingredient is quality...in thinking and doing...that has made the name "Houdaille" on any product a guarantee of superiority.

● HOUDAILLE MANUFACTURING UNITS:

BUFFALO ARMS, INC. *Akron, New York*
Automatic weapons and components.

BUFFALO HYDRAULICS DIVISION *Buffalo, New York*
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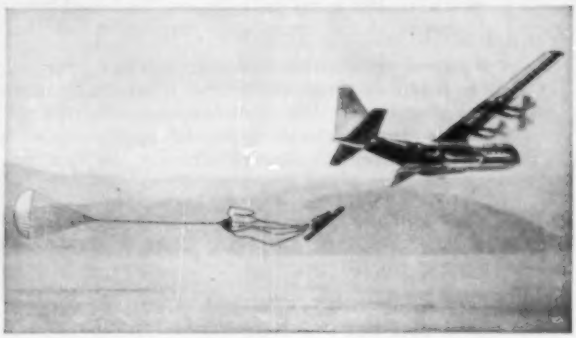

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From the President's Desk

Professional Recognition

The wide spread growth of quality control in industry makes abundantly clear two major facts about our work:

1. Quality control activity is now a specific technical field of its own.
2. Increasingly it must be viewed as one of the major technical professional fields—like industrial engineering, electronics engineering, thermo-dynamics engineering.

While these facts about quality control professionalism are recognized by many of us in the activity, we must accept the present realities of the matter: The activity is not yet recognized as professional in many areas of industry, nor by some other professional engineering societies, nor certainly by most state professional engineering licensing boards. One of our major tasks in ASQC for the near and long-term future must be, therefore, the development of this recognition.

Professional recognition for quality control engineering must be earned. It can be earned only by accomplishments both in our technical contributions to industry and by our acceptance and discharge of the community responsibilities that are inherent in the obligations of any profession.

We need to establish specific goals for results in both of these areas. In the technical area, for example, we must determine what really are the specific engineering contributions we make to industry that warrant professional recognition. Are they in better product design? In better testing practices? In improved inspection technique? In pre-production pilot run procedures? In substance, we must determine the basic elements of technical work in quality control that we consider to be professional.

We must similarly determine just what it is that we do and propose to do for the community. Is it to help set codes for product quality standards? Is it to work for progressively higher product quality performance?

Because these are questions of current concern to all of us in the Society, your officers are presently devoting much attention to them. As you know, the recent amendments to our constitution have taken some major steps toward further professionalism in our Society's work. We are now at work on four additional steps to assist ASQC in fully implementing the intent of these amendments. These steps are:

1. The development of a definitive document which spells out the concept of quality control engineering work underlying professional status.
2. A coordinated effort by the Society through local sections and with employers of quality control engineers to encourage a trend so that the Society's documented concepts of professionalism would conform with company employment standards.
3. A formal Society program—also tied in with local sections and with employers—to encourage self-education on the part of preliminary grade ASQC members to improve their professional status.
4. The documentation of the appropriate areas of national, state, and local community contribution by the Society.

These activities do not by any means indicate that we seek to set unrealistically rigid criteria for professional status such as graduation from specific technical schools.

The criteria must simply be demonstrated ability to do a qualified quality control engineering job—independent of the educational sources from which these abilities were derived.

Of course, as time goes on, we would hope to encourage more and more universities to offer degree level training in quality control. This would be equivalent to some of the learned-through-experience criteria for professional qualification.

Quality control work has come a long way in the United States in the last decade. We must now formalize the hard technical core of this work so that the quality control man can join in comparable professional recognition with his fellow members of the engineering profession in this country.

Dale L. Lobsinger

The Challenge of Total Quality Control

A. V. FEIGENBAUM
General Electric Company, New York, N. Y.

Editorial Note

Portions of this article are a restatement of ideas expressed by the author in an article contributed by him which appeared in the May 1956 issue of *Industrial Quality Control*. They are, however, sufficiently significant to deserve repetition, and they are vital to the development of the theme of "total quality control" as herein presented.

Your attention is invited to a careful study of the philosophy and concept of quality control as expressed by Dr. Feigenbaum in this article.

M. E. W.

THERE has been an unusual degree of quality control progress throughout the United States in recent years. Through the efforts of many groups and individuals, there has been a very wide growth in understanding about the broad scope, the technical emphasis, the organizational character, and the growth opportunities of the quality control field.

One of the keys to this progress that I see from coast to coast is the degree to which industrial top management has come to take quality control really seriously as an overall management activity. The test that many progressive American company presidents apply to their quality control program today is not a test of its adequacy as a statistical analysis effort, nor its adequacy as an incoming sampling activity, nor indeed its adequacy as a matter of shop process control effort. The acid and final test that top management uses is a *business* test—a test of the degree of positive contribution that quality control makes to the effectiveness, service, and profitability of the total enterprise.

This is, of course, because elements of product quality are deeply entwined with the very roots of a company—with its marketing activities, with its inventory control, with its product planning, even with its industrial relations. A mature, genuinely satisfactory modern quality control program is one which, on an overall, factory-wide basis, regularly comes to grips day by day with all of these product quality elements. The program may be modestly organized in its early days as a matter of reject analysis alone, incoming sampling alone, process analysis alone. For maximum contribution to business effectiveness, however, its ultimate goal must be overall control of product quality wherever this quality is to be found.

The Modern Quality Control Goal

This is a goal under which quality control becomes a genuinely top-level management program in a company—comparable directly with other top-level management programs such as Production Management, Budget Control, Materials Management, Personnel Administration. It is, in effect, the goal for building the modern quality control function.

I would like to take the liberty of offering some of my views about what we quality control men must do to achieve this goal toward which there has been so much heartening progress and yet toward which so much more progress still remains to be accomplished before quality control can be recognized as a genuinely mature, first team business management function in the United States. I will try to present these opinions frankly. If they occasionally seem blunt, the justification I offer in apology is simply stated. It is my conviction that, after a decade of explosive and successful quality control growth, a broad and searching appraisal of our objectives is in order. We must make sure that our policies and programs are squared up with the current realities of industry.

I am also convinced that this, our professional journal, is the medium for such an examination. How should we organize? How should we train people? How should we establish plans and programs? How should we develop equipment fully to achieve our product quality objectives?

Quality as a Business Problem

In coming to grips with questions such as these, perhaps it would be initially worthwhile to look broadly at the quality problem that exists today as a very critical **business** problem.

To design, build and sell products competitively in the 1957 marketplace, American businessmen must take full account of three crucial trends:

1. **Customers, both industrial and consumer, have been increasing their quality requirements very sharply in recent years. This tendency is likely to be greatly amplified by the intense quality competition that seems inevitable in the near future.**

   For example, the electrical relay that could command the lion's share of the 1952 industrial market is no longer acceptable for 1957 operating needs. Consumers are progressively more minute in their examination of the finish of appliances, or in their judgment of the tone of a radio or television set. Even for military products on which quality has always been the major consideration—jet engines, airborne electronics, ordnance—specifications are continually being made more rigorous.

2. **As a result of this increased customer demand for higher quality products, present in-plant quality practices and techniques are now, or soon will be, outmoded.**

   Thus, the machined part that could once be checked with a pocket scale or a pair of micrometers must now be carefully measured with an air gauge. Material that could once be visually accepted if it were "reddish brown and shiny" must now be carefully analyzed both chemically and physically to assure that it is beryllium copper instead of phosphor bronze. At the same time, automation, in

which rapid quality evaluation is a pivotal point, has magnified the need for mechanization of inspection and test equipment—much of which is now in the hand-tool stage.

3. **Quality costs have become very high. For many companies they may be much too high if these companies are to maintain and improve their competitive position over the long run.**

In fact, quality costs (inspection, testing, laboratory checks, scrap, rework, customer complaints, and similar expenses) have crept up to become a multimillion-dollar item. For many businesses they are comparable in degree with total direct labor dollars, with distribution dollars, or with purchased material dollars! Evidence points strongly to the fact that many businesses have quality-cost expenditures representing 7, 8, 10 percent, and even more of their cost of sales!

Taken together, these three trends spell out the twin quality objective of modern American business management: first, considerable improvement in the quality of many products and in many quality practices, and, second, substantial reductions in the overall costs of maintaining quality.

Total Quality Control

In my opinion, the business key to meeting these objectives lies in a kind of activity that we might call "*total quality control.*"

The underlying principle of *total quality control* is that, to provide genuine effectiveness, true quality control management must start with the design of the product and end only when the product has been placed in the hands of a customer who remains satisfied. Furthermore, it must foster the right product quality cost during the entire effort.

The reason for the breadth of this activity is that the quality of any product has been affected not at one but at many stages of the industrial cycle: For example, take the case of an electrical relay:

- Marketing evaluates the level of relay quality which customers want and for which they are willing to pay.
- Engineering reduces this marketing evaluation to exact specifications.
- Purchasing chooses, contracts with, and retains vendors for parts and materials.
- Manufacturing engineering selects jigs, tools, and processes for relay production.
- Manufacturing supervision and shop operators exert a major quality influence during parts making, subassembly, and final assembly.
- Mechanical inspection and functional test check conformance to specifications.
- Shipping influences the caliber of the packaging and transportation.

In other words, the determination both of quality and of quality cost actually takes place throughout the entire industrial cycle for the relay. This is the reason why real quality control cannot be accomplished by concentrating upon inspection alone, or design alone, or reject-trouble-shooting alone, or operator-education alone, or statistical analysis alone—important as each of these individual elements is. The breadth of the job requires instead—to restate the point—a broad-gaged thoroughly competent business management function which has a technical relationship with product quality at *all* stages of production.

Like traditional inspection, this quality control function is still responsible for assurance of the quality of products shipped, but its broader scope places a major addition upon this responsibility. Quality control becomes responsible for quality assurance at *optimum quality costs.*

In total quality control, therefore, the typical quality control man is basically a *quality control engineer* —with an adequate background of the applicable product technology, and with training in statistical methods, in inspection technique, and in other tools useful in the improvement and control of product quality.

Other Quality Control Philosophies

How widely accepted *is* total quality control? Not yet very widely, if we are to judge by the degree of its use by quality control men in industry.

It may, therefore, serve further to clarify the character of the total quality control management concept if we compare it with other philosophies that are currently very popular. Actually, there have been, and are today, a great many different concepts of the meaning of the term "quality control." The two most widely accepted of these concepts are probably first, what might be called "inspection quality control;" and, second, of course, the concept of "statistical quality control."

Let's turn first to inspection quality control. This activity as practiced today essentially sums down to the traditional inspection function updated and made more efficient by use of certain statistical methods and work-in-process inspection routines. For one example:

- Statistically verified sampling plans assure the quality of outgoing lots better and more economically than do the older 100 percent inspection or the hit-or-miss spot check procedures. For another example:
- In-process sampling inspections detect quality errors before too many bad parts have been produced, and are consequently more effective than concentration on final inspection with its risk of producing a large number of bad parts.

The fundamental job, however, is still the historical factory inspection job which is intended to protect the customer by screening bad material from good prior to shipment. The chief inspector is still essentially confined to shop floor controls. The typical quality control man is still basically a well grounded inspection specialist who has had training in useful statistical methods.

True, an impressive weight of dollars-and-cents evidence demonstrates that inspection quality control does indeed represent a great improvement over older inspection practices. And probably most systems called quality control in American business today are examples of the inspection quality control view.

Now for the second most popular concept—statistical quality control. This approach, as is so well known, reflects the major and increasing contributions that probability methods are making to the improvement of industrial decision making. And the statistical quality control concept predominates, of course, both in the literature of quality control and in professional meetings on the subject. It sees the typical quality control man as a competent industrial statistician, who works on problems ranging from the design of laboratory experiments, through the establishment of control charts for production processes, on to the analysis of manufacturing rejects. It sees him, in other words, as capable of making contributions in fields not directly connected with product quality, such as time study, and safety.

Limitations of the Concepts

In my experience, both the inspection quality control concept and statistical quality control concept have been and are today highly useful in the areas of product quality

which they cover. But as compared with total quality control, I am forced to suggest categorically that their scope is much too limited; that they are able to provide only a partial grasp of the overall quality control problem that faces American businessmen.

This is because the inspection and statistical concepts of quality control are simply not adequately geared to the fact that quality considerations are involved in every phase of industrial activity; they are not geared to deal with total costs of quality; their responsibilities and authorities are not geared to effort that is adequate to keep these costs at a minimum; their technical engineering content is too low for the technological complexities of today's product quality.

In my opinion inspection quality control and statistical quality control —popular as they may be today— will ultimately be recognized, not as ends in themselves, but basically as progress markers on the way toward our real quality control management goal of total quality control.

I do not minimize at all the fundamental problems that face quality control men in converting inspection and statistical programs to complete quality control programs—problems of organization, of manpower, of salesmanship. But frankly—and this may seem surprising—I believe that total quality control represents a concept that is in the long run much more saleable to, understandable by, and acceptable to industrial top management than are the inspection and statistical concepts.

The inspection concept no matter how useful it has been in fact, has in actual practice always been received with substantial reserve by some members of top management. They have—and not without justice —considered the traditional screening inspection process, no matter how much up-graded, as a necessary evil, as a "no value added" activity that is necessary only in the way that policemen are necessary. They have seen inspection budgets as something that must be borne with but which should be trimmed whenever and as soon as possible. They have simply not considered the inspection activity as a member of the management first team, and have not accounted for it in major planning for the business.

And the statistical quality control concept, good as it is, has often not been taken by some members of top management even as seriously as they have taken inspection quality control. After all, to a businessman whose responsibility is to his company's overall performance, statistical quality control is at best an important technique with broad application. Unlike marketing, or industrial relations, or production, however, it is not a fully integrated function to meet basic business objectives.

Reliability Quality Control

While statistical and inspection quality control are unquestionably the most popular, there is another current concept that is becoming increasingly recognized. It can be termed "reliability quality control." Further significant insight may be cast upon the nature of total quality control if we briefly relate it to this reliability quality control concept.

Product performance-over-time requirements today are being spelled out in many specifications. These "reliability" requirements are achieved through well understood procedures in long established product lines like locomotives or turbines or generators. However, they create major new quality problems in more recent technologies like electronic assemblies which use thousands of components.

To some organizations, solutions of these reliability problems have seemed somewhat unrelated to the application of statistics or of inspection. New, powerful, and useful techniques have, therefore, been developed—techniques, in fields like environmental analysis and non-destructive testing.

Just as was the case in years past with inspection and statistical techniques, these reliability techniques themselves have gradually crystallized into a quality control activity of their own. Quite understandably, some of reliability quality control's practitioners consider their activity at least as technical and specialized as—and, therefore, different from— the statistical and inspection activities.

Nonetheless, and despite its contributions, reliability quality control shares some of the inadequacies of these activities. Like them, its scope is far too limited as compared with the total industrial quality problem.

Product performance-over-time, while very important and currently the object of much attention, still represents only one of the major interdependent elements in the definition of the quality of a product. *All* such elements are extremely important and *all* require effort to achieve the overall product quality which will provide satisfactorily reliable customer performance. The achievement of product reliability is operationally interrelated with many other company quality programs: for instance, with incoming material controls or with in-process controls. It cannot really be achieved as an activity separate and distinct from these other programs, no matter how powerful the individual techniques it employs.

Because it has come to prominence later than the statistical or inspection concepts, reliability quality control has generated some additional, negative management reactions. These have to do with the possibility of costly pyramiding of the various quality control activities. There is concern about overlaps between reliability quality control and the other specialized quality control concepts that may be operating in the plant; concern about its possible competition rather than integration with these other concepts; concern, in certain cases, about the extent to which the reliability approach differs from these concepts more in the fresh emphasis of its language than it really does in strong new tools that it brings to the plant.

Management men have questioned the rather forced attempts to reconcile reliability quality control with the other concepts through such rationalizations as the following: that "quality" work is basically in-plant and this is the job of statistical or inspection quality control; that, on the other hand, "reliability" work has to do with achieving consistent field performance. Some management people do not consider this a genuinely workable distinction.

For similar reasons, they question equally sharply the opposite rationalization that is occasionally offered: that if consistent field performance is emphasized, then reliability quality control can largely replace the in-plant work of inspection or statistical quality control.

Certainly, the business quality problem is made no easier when top management is faced periodically with reconciling the various special-purpose quality control concepts. Management may feel a deep and continued doubt concerning what "quality control" is really all about. It wonders when the now-new reliability quality control concept will itself come into conflict with a still newer special-purpose concept of quality control. It wonders why quality control people can't adopt a common language, and why they can't deal with quality problems as management sees them.

Total Quality Control Most Acceptable

To sum up this part of my message, therefore, I propose that total quality control not only is the function which can do the broad quality control job needed by American business today, but—as an inevitable corollary—it is also the quality control concept that is most acceptable to American business: because it is an integrated whole; because it operates at lower cost; and because it comes to grips with the *complete* range of product quality and quality cost problems as top management sees these problems. As a result, total quality control is an activity that can begin to give truly technical and professional status to quality control men. But more about this in a moment.

Now let's turn directly to management of the quality control function on this broad basis:

The work of the function may be classified into four broad jobs*

1. **New design control,** or the planning of controls for new or modified products prior to the start of production.

2. **Incoming material control,** or the control of incoming purchased parts and materials.

3. **Product control,** or the shop floor control of materials, parts, and batches from machines, processes, and assembly lines.

4. **Special process studies,** or the conducting of special analyses of factory and processing problems.

In these four jobs, the modern quality control function has, it may be worth re-emphasizing, two basic responsibilities:

First: To provide *QUALITY ASSURANCE* for the business's products: that is, simply, to be sure that the products shipped are right.

Second: To assist in assuring *OPTIMUM QUALITY COSTS* for those products.

The quality control function fulfills these responsibilities through its three sub-functions: which are *quality control engineering; inspection;* and *test.* They in turn operate three activities, which form a continuous feedback cycle:

(1) *Quality planning* is done by quality control engineering; this establishes the basic framework of the quality control system for the business' products.

(2) *Quality measuring* is performed by inspection and test; this determines, in accordance with the quality plan, the conformance and performance of parts and products with engineering specifications.

(3) There is rapid feedback to quality control engineering for *quality analysis,* which results in new planning, thus completing the cycle. This analysis also fosters corrective action for product quality deviations.

Quality Control Engineering Work

The true nerve center of the modern quality control function is this engineering component. Its feedback cycle activities deserve examination in some detail as they fit into the four quality control jobs:

First: New Design Control

In this area, quality control engineering provides three main activities:

1. Preproduction service to design engineering and manufacturing engineering in analyzing the quality-ability of new products and production processes, and in de-bugging quality problems. This assures a product which will be as defect-free as possible *prior* to the start of production. Among the new technical tools which the quality control engineer brings to this effort are process quality capability studies, tolerance analysis technique, pilot run practice, reliability analysis, and a wide variety of statistical methods.

2. The planning of inspections and tests to be carried on when production is under way on the new product. This is to establish continuous control of in-process quality. It involves determining the:

- Dimensions and characteristics of the parts to be checked.
- Degree to which they are to be checked.
- In-process and final production points at which checks are required.
- Methods and procedures to be used—including statistical sampling plans, control charts, etc.
- Personnel who will make checks; that is, which shall be done by production operators, and which by the inspection and test subfunctions.

3. Design of modern inspection and testing equipment. This is genuine quality control equipment rather than merely mechanized sorting. It is physically integrated to the fullest possible extent with manufacturing equipment to permit the machine to check its own work. The aim of this design activity is economical investment expenditures, maximum equipment utilization, and fullest practical mechanization and automation both of operations and of quality control paperwork.

Second: Incoming Material Control

In this area, quality control engineering must assist in the establishment of good quality relationships with suppliers. It contributes to this objective in the following ways:

- By planning the periodic rating of the quality performance of present suppliers, it provides facts which assist the purchasing function in quickly bringing satisfactory or unsatisfactory quality performance to the attention of vendors.
- By evaluating the quality capability of potential suppliers, it provides facts which assist purchasing to select good quality vendors.
- By working with the vendors, it assists them in understanding the quality control requirements of the purchase contracts they have won.
- By establishing quality certification programs, it places the burden of quality proof on the vendor rather than on an extensive, expensive in-plant incoming inspection effort.

Third: Product Control

In this area, quality control engineering carries on the cost measurement and quality cost reduction project activity required for over-all quality cost control and reduction; and it works closely with the inspection and test sub-functions which perform the actual measuring work. It also performs process quality capability studies to determine the quality limits within which a machine or process may be expected to operate. The aim is to make sure that parts will be routed to equipment which is capable of economically maintaining engineering specifications.

Fourth: Special Process Studies

In this area, the job of quality control engineering is to analyze complex, in-process quality problems which have been fed back to it by inspection and test. These studies are directed both to the elimination of defects and to the development of possible improvements in present quality levels.

The Professional Quality Control Engineer

Certain elements of this quality control engineering work have been previously performed on a sporadic basis. But the quality control engi-

*This structure is after the book *QUALITY CONTROL: Principles, Practice and Administration;* A. V. Feigenbaum; McGraw-Hill; New York City.

neer himself is something new under the sun. Quality control engineering is not merely a new label for the inspection planning package, nor a fresh designation for the test equipment engineer; nor yet a technologically flavored title for the industrial statistician. It is, instead a specialized technical activity with a character all its own, calling for a unique combination of skills in appropriate phases of product and process technology, as well as in the quality control technique itself.

Quality control engineering work is the product of cross-fertilization of several modern developments—in statistical methodology, in fast-response, high-precision inspection and testing equipment, in management engineering progress in developing the control function in modern business.

In experience, education, aptitude, and attitude, the man we see entering quality control engineering work today is, in fact, not very different from the man entering other longer-established major technical fields, for example, product engineering or manufacturing engineering. He must possess, or have the capacity to acquire, the necessary product and process background. He must have the personal characteristics to work effectively in a dynamic atmosphere with people of diverse interests. He must possess the technical background which will enable him to acquire, if he does not already have it, the growing body of quality control engineering knowledge. Finally, he needs the analytical ability to use this knowledge in solving new and different quality problems. In this broad type of quality control engineering I think we are beginning to see the emergence of a truly new professional activity in the engineering sector of the American economy.

Quality Control Inspection and Test

It is worth noting that the planning and analysis work of the quality control engineer, in turn, makes possible the employment of a new, more positive type of inspector and tester. Instead of *policing* the manufacturing process, the modern inspector and tester becomes a direct part of that process team by *assisting* in the production of good quality products.

This positive type of quality control inspection requires only a very minimum of routine, hand-sorting inspection and test as we have known it in the past. Instead, the inspector and the tester do genuine quality assurance work. They provide genuine assistance in the production of the right quality by:

first—becoming auditors of the good quality practices that have been established by quality control engineering;

second—by providing to foremen and operators as much as possible on-the-spot shop floor analysis of defects;

third—by feeding back when necessary facts about these defects for corrective analysis and action elsewhere.

Such work of course means the up-grading of traditional inspection and tests as we used to know it. As compared with this older activity, *quality control inspection and test* requires many fewer but much more highly qualified and more specialized people—those who have genuine ability to be helpful in making the right quality. An instance in point is the arc-welding inspector, who not only knows whether or not weld penetration on a part is satisfactory; but also, in the case of defective welds, may be able to counsel the shop on why the penetration has been unsatisfactory.

Two Organization Principles

Perhaps it would be appropriate to pause for a few moments to turn to the important question of just how this total quality control activity can be organized for a company. Experience shows, I think, that two organizational principles are basic to guide us here.

Principle number one is that *quality is everybody's job* in a business.

In defiance of this principle, there have been many company experiments over the years which have attempted to make the quality activity cycle less of a decentralized, Tinkers-to-Evers-to-Chance sequence. Often these attempts have taken the form of centralizing all quality responsibility by organizing a component whose job was handsomely described as "responsibility for all factors affecting product quality."

These experiments have had a life span of as long as six months—when the job incumbent had the advantage of a strong stomach, a rhinoceros hide, and a well-spent and sober boyhood. Others not similarly endowed did not last six months. For the simple fact of the matter is that the marketing man is in the best position to evaluate adequately customer's quality preference; the design engineer is the only man who can effectively establish specification quality levels; the shop supervisor is the individual who can best concentrate on the building of quality.

Total quality control programs therefore require, as a first step, top management's re-emphasis on the responsibility and accountability of *all* company employees in new de-

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sign control, incoming material control, product control, and special process studies.

The second principle of total quality control organization is a corollary to the first one. It is that *because quality is everybody's job in a business, it may become nobody's job.* Thus the second major step required in total quality programs becomes clear. Top management must recognize that the many individual responsibilities for quality will be exercised most effectively when they are buttressed and serviced by a well-organized, genuinely modern management function whose only area of specialization is product quality, and whose only area of operation is in the quality control jobs.

Some Results

Experience in an increasing number of companies shows that operation of the total-quality-control program has paid off handsomely. For one example, a midwestern company manufacturing motors installed a total-quality-control activity, which in 12 months (1) improved product quality substantially, (2) reduced field complaints several fold, and (3) reduced the going level of quality costs from an annual rate of about a million dollars a year to a new annual rate of something over $600,000—a total savings of almost $400,000. And during this period, output increased about 10 percent.

More broadly, total quality control in the United States has resulted in six important improvements.

- Better product quality
- Reduced scrap, complaint, inspection, and other quality costs (Improvements of one third or more in over-all quality costs are not unusual.)
- Better product design
- Elimination of many production bottlenecks
- Improved processing methods
- Development of a better spirit of quality-mindedness on the production shop floor.

Certainly our experience with this program has been highly satisfactory in the General Electric Company, where we have been developing this concept and procedure for some years.

Quality Costs

Thus in its actual practice total quality control successfully meets business' twin-sided quality problem of better quality at lower quality costs. The reason for the satisfactory better quality can be clearly understood from the very nature of the prevention-centered step-by-step technically thorough program. But the explanation for the accompanying by-product of lower over-all quality cost may not be nearly so obvious.

The reason for the favorable cost result of total quality control is that it cuts the two major cost segments of quality (which might be called failure and appraisal costs) by means of much smaller increases in the third and smallest segment (prevention costs). Why this is possible can be seen as soon as the character of these three categories is considered:

(1) *Failure costs* are caused by defective materials and products that do not meet company quality specifications. They include such loss elements as scrap, spoilage, rework, field complaints, and so on.

(2) *Appraisal costs* include the expenses for maintaining company quality levels by means of formal evaluations of product quality. This involves such cost elements as inspection, test, quality audits, laboratory acceptance examinations, outside endorsements.

(3) *Prevention costs* are for the purpose of keeping defects from occurring in the first place. Included here are such costs as quality control engineering, employee quality training, and the quality maintenance of patterns and tools.

In absence of formal nationwide studies of quality costs in various businesses, it is impossible to generalize with any authority about the relative magnitude of these three elements of quality cost. However, it would probably not be far wrong to assert that failure costs may represent from one-half to three-quarters of total quality costs, while appraisal costs probably range in the neighborhood of one-quarter of this total. In many businesses, however, prevention costs probably do not exceed one-tenth of the quality cost total. Out of this 10 percent, usually 8 to 9 percent are directed into such traditional channels as pattern and tool maintenance and the specification-changing or interpreting work of product engineering. This leaves only 1 or 2 percent for elements of quality control engineering work.

It is a significant fact that, historically, under the traditional inspection function, failure and appraisal costs have tended to move upward together, and it has been difficult to pull them down once they have started to rise. The reason for this relationship is that:

As defects increase—thus pushing up failure costs—the number of inspectors has been increased to maintain the "they shall not pass" screen to protect the customer. This has pushed up appraisal costs.

For the reasons mentioned earlier in this article, screening inspection does not have much effect in eliminating the defects, nor can it completely prevent some of the defective products from leaving the plant and going into the hands of complaining customers. Appraisal costs thus stay up as long as failure costs remain high. The higher these failure and appraisal costs go, the higher they are likely to go without successful preventive activity.

Why Quality Costs Drop

Once these two main elements of quality cost have started to rise—as they seem to have throughout industry generally today—the one best hope for pulling them to earth again seems to be spending more on the third and smallest element, namely, prevention cost. The 10 percent now spent may well need to be doubled, much of the increase going for quality control engineering as well as for improved methods of inspection and test equipment automation.

At first glance such increases in prevention costs may not seem to be in the interest of quality cost improvement, but this objection is rapidly dispelled as soon as results are considered. Translated into quality cost terms, the operation of total quality control has the following sequence of results:

(1) A substantial cut in failure costs—which has the highest cost reduction potential of all quality cost elements—occurs because of the reduced number of defects and the improvements in product quality brought about by modern quality control practice.

(2) Fewer defects mean somewhat less need for routine inspection and test, causing a reduction in appraisal costs.

(3) Better inspection and test equipment and practices, and the replacement of many routine inspectors by less numerous but more effective quality control inspectors and testers, bring about additional reduction in appraisal costs.

(4) Because the new quality control inspection and test is effective in preventing defects, appraisal dollars for the first time begin to exercise a positive downward pull on failure costs.

Quality Dollar Budgeting

It is worth noting that this identification and analysis of quality costs permits a major forward step in the business budgeting process. It makes feasible establishing the dollars needed for quality control, not on the basis of historical inspection cost experience, but on the basis of current company objectives in product quality and quality costs.

Quality needs and problems differ so much from company to company that it is not realistic to generalize about the specific mix of quality costs that should be budgeted under total quality control. But the direction of budgetary trends may be suggested by an example, which embodies current industrial experience in this area.

Table I shows how one company expects to cut its quality costs by a total quality control program. The company anticipates that total quality expenses will drop from the current high of 7 percent of sales to 5 percent, with declines achieved both in failure and appraisal costs while prevention costs increase from 0.70 percent of sales to a still modest 1.25 percent. In this example, the cost savings budgeted are rather moderate, owing to the presence of complicating factors such as the following:

- An anticipated 50 percent increase in sales over the next five years —from $50 million to $75 million.
- Planned additions to a product line that is already highly technical and diversified, hence accompanied by major quality problems.

Such a planned 30 percent improvement in quality cost ratios is feasible, indeed conservative, with a successful total quality control program—even with a 50 percent business expansion and even with counterbalancing quality cost increases brought about by the introduction of new products. While the company in the example may not be typical (probably there is no such thing as a typical business enterprise), it is at least illustrative of the good results that can be achieved even when circumstances pose unusual difficulties.

The ultimate end result of total quality control, therefore, is that its program to improve product quality also brings about both a sizable reduction in total quality costs, and a major alteration in the proportions of the three quality cost segments. No large, long-term personnel increase in the overall quality control function is required as a necessary condition for this quality cost improvement. Instead, the amount of quality control expense, as a proportion of total company expense, will be down in the long run. The personnel mix of the quality control function will, however, change to include a very much higher proportion of professional and specialist-type people.

Summary and Conclusion

In summary, therefore, total quality control represents a major forward step in management science: Its integration of design-through-shipment control of the many elements in the quality picture makes it much more effective than the unlinked fragmentary inspection or statistical controls of the past. Its quality control function, a major new business management activity, provides professional effort in meeting the objective of assured product quality at minimum quality cost.

In this modern quality control function, inspection and test have a chance to develop in the direction that conscientious inspectors and testers have always sought: that is, into an activity with a positive role in assisting other members of the manufacturing, engineering, and marketing team toward quality improvement and quality cost control. No longer are inspection and test confined to essentially a negative, fist-shaking role in sorting bad parts from good, a role placing them continually on the defensive and evoking the hostility of other managers.

TABLE I—Budgeted Quality Costs and Savings Under Total-Quality Control
(Assuming sales increase from $50 million to $75 million)

Quality cost element	Total Dollars		Percent of Sales		Percent of total quality cost	
	Present	5-year goal	Present	5-year goal	Present	5-year goal
Failure	$2,275,000	$2,062,500	4.55%	2.75%	65%	55%
Appraisal	875,000	750,000	1.75	1.00	25	20
Prevention	350,000	937,500	0.70	1.25	10	25
Total	$3,500,000	$3,750,000	7.00%	5.00%	100%	100%

In the integrated quality control function, the many tools of statistical methodology that have proved practical and useful can be brought to their fullest effectiveness. With the quality control engineers as tool builders, and the quality control inspectors and testers as tool users, statistical techniques can be put to work in a down-to-earth fashion that welds them into regular day-by-day controls. No longer will these techniques be treated—as too often in the past—merely as curiosities, to be employed in special situations on a pinch-hitting basis.

With product reliability recognized as a major objective, appropriate elements of its tools and practices can be made an integral part of the work of the quality control engineers and of quality control inspectors and testers.

With equipment for inspection and test a direct and major responsibility of the quality control function, more use can be made of equipment specialists who wish to concentrate their skills on the great needs, opportunities, and unique complexities of today's quality control equipment field.

Total quality control thus welds all of this new technology into a strong yet flexible weapon, capable of successfully coming to grips with the three major quality problems that modern business must face and solve: the upward customer pressure on quality levels; the resulting rapid obsolescence of quality practices; the very high level of quality costs.

Although delivery and other factors may sell a product the first time, it is usually quality that keeps the product sold and which keeps the customer coming back a second and a third time. Quality cost—perhaps 8 percent or more to cost of sales—is one of the major elements of product cost that must be made right to permit the setting of the right price to the customer. Helping to assure this right quality at this right quality cost is the way *the new total quality control* can serve its company in the years ahead—in which product quality, and modern quality control operated as a management function, will be among major factors in the company's survival, health, and progress.

I respectfully submit for consideration this conclusion: that learning to build and use these broad, total quality control programs must—fully as much as statistical and inspection specialization—become a major basis for professional skill in the qualifications of we quality control men.

Initiating a Quality Control Group in an Existing Organization

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"There are nine and sixty ways
Of constructing tribal lays
And every single one of them is right."
—Kipling.

Introduction

I shall speak from the viewpoint of a man who has both a genuine and an official interest in an existing organization, who has reason to believe that the organization needs statistical quality control, but who will not, himself, be an active participant in the contemplated quality control organization. The questions to which I hope to present partial answers are:

(1) What should the man do to verify the need for SQC?
(2) If SQC is needed, how should he go about formulating a plan for the SQC organization?
(3) How should he secure the acceptance of the plan?
(4) How should he go about the task of making the SQC group or organization a reality?

I should then like to outline some of the potentialities of a complete quality control organization.

Each of the above questions would deserve more than a separate paper if we were to consider all the combinations of well-known types of organizations and different types of statistical endeavor now included under statistical quality control. Hence, we shall limit our consideration to the more important or more frequently encountered combinations. Let us consider only three types of statistical quality control: process quality control, quality assurance, and operations research; and only two types of organization: multiplant (all shops making essentially the same products) and multidivision-multiplant (divisions producing different end products).

Verifying the Need for SQC

Observing a Production Process

If we wish to consider the need for SQC it is well to first take a walk through the plants of one or more divisions. One should begin where the raw material comes in. One should observe and note each operation, what line inspections are made at each operating station, whether the tolerances appear to be reasonable and whether or not they are taken seriously, and what action is taken with respect to non-conforming products. Similarly, one should note what final or semi-final inspections, if any, take place during the process of production. If process inspection (which should be a "tool" of manufacture, and report to manufacture) is not separate and distinct from final inspection (which should be a "tool" for assurance of quality of outgoing product and report to top management of the division), there should be grave doubt both with regard to the efficiency of the process and the integrity of the product.

The reasons for this condemnation are obvious.

The manufacturing people are not competent to perform inspection relative to the assurance of quality of outgoing product because no man is competent to be the inspector of his own work. Conversely, the final inspector is not competent to do process inspection because he would thereby become a party to the product as manufactured. Furthermore, the primary function of process inspection (process quality control) is not mere detection of non-conformance: it is removal of the *causes* of non-conformance, which means wisely considered changes to be made in the production process, and this is certainly a matter that must belong to manufacture. If either type of inspection consists of blind adherence to arbitrary tolerances rather than comparison of the product at hand with the natural tolerances inherent in the production process, the need for statistical quality control is apparent.

In the walk through the plant, one should note particularly the validity of the sampling and inspection process. If multiple lines of components flow into a sub-assembly, or if multiple lines of bulk product flow into a single line (like the tributaries of a river), one must see to it that increments of each sub-flow are sampled and the sampled increments kept separate and distinct until their quality has been verified by inspection of the samples.[1] All too often one finds that process inspection (or perhaps an inspection that is neither identified as process or final) takes place after several tributary lines have flowed together and have lost their identities. When this condition obtains, trouble in a single tributary line can result in contamination of the product from all lines with which it is mixed; the cause of poor quality is obscured, and management becomes accustomed to accepting poor or variable quality as normal.

Of course, these and a number of other observations should be made in each plant of the organization. The engineering validity of the process is as important, if not more important, than statistical treatment of data, because sound engineering treatment is a prerequisite of statistical quality control.[2]

Quality Discipline

The attitude of persons on the job is important. Is a record kept of each inspection? Too often the operator measures a sample of ten, and flips them back into the line with the remark, "Only one of them was out a little." Even when a record is kept, one finds all too often that no attention is paid to non-conformity, unless the non-conformance is huge.

Organizational Evidences of Quality

An important key to the need for SQC inheres in "loss" or "scrap" reports. These should be examined in the presence of management, both for the reason of soliciting background information and for the purpose of bringing frankly into the open the ills that need curing and for which there are possible cures.

The points in the production process where the losses are large should be noted carefully and you should consider how these losses may be related to the observations that you made while inspecting the production line. Raise the question as to whether all of the losses are really poor quality or only apparently so. It is often apparent to the experienced quality control engineer that specifications are not consistent with the level of quality inherent in the production process and that the rejected material is neither better nor worse than the accepted material. The ratio of inspectors to production supervisors and to volume of work should be noted. One should note also to whom each inspector (process or final) reports: his boss is the determining feature as to whether his loyalty is to "Q" for quantity or to "Q" for quality.

One should find out if the company's product is satisfactorily competitive in its market both with respect to quality and to price. By this time our investigator should know rather assuredly whether the organization leaves much to be desired, even if he is not sure that the desired thing is SQC.[3]

Summarizing, then, the information gathered in answering question one, the man should have noted the presence or absence of the most important factors that constitute good quality control:

1. A proper balance between manufacturing, engineering, and inspection.
2. Good quality communications concerning goals and results.
3. Good process engineering information.
4. Quality awareness.
5. The quality history of the company.

Formulating a Plan for a SQC Organization

At this point the investigator should go into a dark brown study with respect to question two: how to formulate a quality control organization. Basically, this study is a series of null hypotheses: if SQC could be established on this operation, what savings could be expected in time, labor, material, and scrap? What personnel can be saved? What degree of improvement in quality is a reasonable expectation?

Bases for the Formulation of a SQC Plan

If the precision inherent in the production is such that with proper adjustment the production limits can be made to fall within the specified limits, then practically all the scrap can be saved. If, on the other hand, the precision inherent in the process is such that the spread of product is greater than the spread between the specified limits, the percentage of scrap can still be substantially reduced in most instances by proper adjustment of mean level of production. Furthermore, if the process is not achieving substantially the precision that is inherent in it, the precision can be much improved, thereby improving the above condition.[4] On these grounds, the initial design of the quality control system may well be focused on the points in the process where high losses occur.

Cautions Relative to a SQC Plan

However, the flow of product toward the loss points must be examined critically. If the product that is incurring the loss is composed of sub-assemblies, each sub-assembly must be statistically controlled. Furthermore, it may be necessary to go behind the sub-assemblies, and control the materials of which they are made.[5]

If the product that is incurring the loss is made up of several raw materials, either all of these must be brought under statistical control (if their effects are significant) or each must be subjected to a blending process that will assure a satisfactory stability of quality. A single simple procedure almost never suffices. Quality level and uniformity must be controlled all the way from raw material to the final critical point. The nearer a product is to the earth, and earthy, the more difficult it is to control.

One should be wary of the extractive industries. Their products are likely to be "batch lots," and to vary from batch to batch, depending on where they were seized from mother nature. Blending procedures must be devised to control them, and the task partakes much more of engineering than of statistics.[6]

The Outline of a Plan

Based on this type of study, one can estimate the number of points at which one must institute sampling of the incoming raw product; the kind of sampling that it must be, i.e., sampling of discrete objects or bulk material; the tests or measurements that should be made; how the test results will be treated, e.g., $\overline{X}$ and R-Chart, p-Chart, etc.; and what corrective action is feasible such as blending or grading. Similarly, one can estimate the points in the production process at which SQC inspections should be made, the initial frequencies of the inspections, the character of the analyses required, the actions to be taken consequent to the inspections. Based on these data, one can design forms to be kept by the operators or sub-inspectors, and can plan the points at which quality control inspectors are needed. However, these plans must, of necessity, be approximate only, for it is doubtful if anyone is wise enough to devise even a moderately good SQC system without a trial and error period.

In a small plant with simple process, the trial and error period that leads to a practical and successful system can be directed by a single QC engineer with some intelligent, although relatively untrained assistants. However, the trial and error period for a large and

complex system of manufacture will require a considerable number of competent statisticians. When Army Ordnance wished to install SQC on complete rounds of ammunition, it made a contract with the Bell Telephone Laboratories to devise, install, and initially operate the QC system. Then, by assigning a few QC engineers of its own, plus some assistants, as "opposite numbers," and by instituting a training program, Army Ordnance personnel were able to take over the operation of the system. Most plans should be somewhere between these extremes.

Securing Acceptance of the SQC Plan

Whom to Sell on Quality Control

After the investigator is able to at least outline the plan, he is ready for step three: to try to secure acceptance of the plan. And the plan should be "sold" at the highest feasible point in the organization.[7] Anyone who thinks that merely sound merit will sell a theory to the rank and file is naïve. It does no good to try to sell it to the inspectors. They may not understand it but they have a sufficient instinct for the preservation of their own power and prestige to sense that it forebodes placing an agency that will know more about the product than they between them and the producers. It does no good to try to sell it to foremen (or generally to plant superintendents). They are "kings in their own realm;" and not only do not relish change, but sense a substitution of scientific technique for experience and native aptitude which is their stock in trade. Actually, both of these classes of people stand to be benefited, but generally they are either not big enough to see it, or are not imaginative enough to wish to try it. The "sale" must be made to a man who is sufficiently high in the organization to have overall responsibility for the success of a whole segment of the organization, and who has the authority to direct a change. The higher the man in the organization, the higher is his sense of responsibility, the more is his knowledgeability, and the more readily is he sold on something that will contribute greatly to the benefit of the whole organization. The sale should be made to the general manager of the plant, the director of manufacturing, or the president, if practicable.

The Proper Attitude of the SQC "Salesman"

This does not mean that a proponent of SQC may adopt a cavalier attitude toward those below the man he sells. It simply means that the top manager must be the *first* one sold. As each man is sold, the next one below him becomes an important selling point, for nothing succeeds without good will. One merely begins on the top floor and walks down; not on the bottom floor to walk up. The QC engineer should take a genuine and friendly interest in every man down to the lowest operator. The QC engineer stands a good chance of benefiting each man, and each man potentially can contribute to the good of the SQC system.[8]

The savings that can be expected to accrue from the plan should be estimated, but care should be taken not to overstate the case. It would be better to subtract three standard deviations from the estimate, because it will still be quite sufficiently desirable, and one will escape the accusation of over-promising. However, one should point out that the immediate increase in profits may not be the most important consideration in adopting SQC. With the achievement of control of process, one can do much to manufacture down to an economic market, up to a quality market, or produce for a graded market with the grades price-marked *right* relative to cost. In almost all instances, SQC is really the only economic way for knowing the real quality of product of a plant. It is the key to any really effective Quality Assurance Program.[9]

Administrative Advantages of SQC

For the multidivision, multiplant organization, a real knowledge of quality of product for each plant is an important management tool. This knowledge is not only important in evaluating customer reaction, but is highly important in evaluating plant management, for consideration in connection with promotions, and for the distribution of bonuses or other incentives.

Furthermore, it is important to know one's own product with assurance, before attempting to compare it with a competitor's. The comparison of one's own uncontrolled product with a competitor's uncontrolled product is most unremunerative; almost all one knows is the difference between the few samples that one happened to test. This is true because the individual increments of an uncontrolled product generally vary widely, and it is impossible for one to infer the quality of the general flow of product from the quality of a single unit or even a sample.

That is why so many firms go year in and year out with no real knowledge of where they stand relative to their competitors. Occasionally they take some samples and test them. They tend to remember the instances that were favorable to their own products; and try, with amazing success, to forget the others, unless the unfavorable comparison was so overwhelming as to demand action. Whereas, an assured knowledge of the quality of one's own product is not a complete answer to this dilemma, it is at least half the answer. If tests of the competitor's product are plotted on one's own control chart (or tests of significance applied), one can soon build up strong, and truthful, evidence for or against the relative values.

Management Advantages of SQC

Finally, all medium and large size companies are into Operations Research today, whether they wish it or not and whether they know it or not. Management cannot intelligently make a decision as to whether to diversify along a certain line, whether to acquire a certain small company, whether to merge with another company, or even whether to build a new plant, without indulging, with more or less ineptitude, in this powerful aid to the decision-making process. One needs in some way to estimate the probabilities of various alternatives, to compute the costs of the consequences of choices, and to arrive at valid expectancies. Even if a firm has some market analysts in its employ, it needs more than that. The higher type quality control engineer should not only be conversant with operations research, but also know his abilities and limitations, and when to go for help. Some members of the QC group can either be

graduated into an operations research group, or even by spending part-time in this field, can do staff work that is a powerful aid in the manager's decision-making process.[10]

Making the SQC Group Operational

How to Install SQC

Making the SQC group a going reality is almost dictated by the plan and the terms under which it is "sold" to management. At the lowest level, the recruitment of a competent quality control engineer is a very minimum. If operations are large and complex the launching of the plan can, perhaps, be done most economically by assembling a crew of experts to design, install and initially operate the SQC system. Concurrently, "opposite numbers" drawn from existing personnel or obtained by recruitment, must be assigned to training so that they can take over the operation from the experts. It is likely to be necessary also to institute an SQC training course for operators and key personnel.[11] However, irrespective of the size of the operation, the cardinal principles are much the same.

A Proper Attitude of the SQC Installation Man

First, one cannot take the lofty attitude that only statistics are one's concern. One's principal concern must be the economic welfare of the company. Nothing that is important to the economics of the company should be neglected, whether one can do it one's self or whether one must secure the services and cooperation of others to do it. This is an especially important consideration even from the selfish viewpoint of SQC, because sound engineering control of process is a prerequisite for statistical quality control of process. Thus, the installers of a quality control system must secure teamwork between themselves and operating personnel to devise alterations in process and in process inspection for the purpose of bringing each stage of the process to a state where it will respond to statistical control. The operating personnel must be made to see that the extra and temporary work and worry is for their future ease, benefit and enjoyment, and for the good of their company. It is very important that the SQC installers and the permanent personnel be friends; and confidence and friendship at each level of management is highly conducive to the promotion of a similar attitude at each successive lower level.

A Controlled Raw Material Is Indispensable

Often the most difficult feature of control of process is control of raw material. One should not regard this problem as not being a part of quality control. The raw material may well come from a plant or plants that do not turn out a controlled product. Thus, a sound system of acceptance inspection of raw material is indispensable to process control. It would be a fine thing if the influx of raw material showed statistical control, but this is rarely the case; and control at the same level by different vendors is almost too much to expect. However, an initially controlled raw material is not generally essential to the establishment of SQC for one's own process. What is essential is identification of the quality characteristics that are important to one's process, inspection for and testing of these quality characteristics, and devising a blending procedure, grading procedure, machine-setting procedure, or other procedure that will adjust sufficiently for variations in the quality of raw materials to keep them from introducing assignable causes of variation in one's own process. This type of inspection and adjustment should be jealously guarded by manufacture, and the responsibility for it assigned to process quality control.

The United Effort of Process Engineering and Statistics

The second step of difficulty in the installation of SQC is the exercise of ingenuity, both in statistics and in engineering, that is necessary to bring a process under statistical control. Changes must be made in the flow of product so that each increment of product arising from a different source can be checked for quality, before it is allowed to mix with other increments and thereby lose its identity. New inspection points must be set up for each of these respective checks on quality (and subsequently old inspection points eliminated). The most knowledgeable people associated with the process must be brought together to seek out the causes of lack of control and devise ways and means for their elimination. This is a great deal of hard work, but also lots of fun, and highly rewarding.

The statistician on this kind of work must also be ever busy in seeing to it that he is employing a valid statistical technique. He must make checks to find out what kind of a universe of effects he is sampling. He must often make tests for checking hypotheses for identifying strong and weak parameters, and for discovering cause and effect relationships that certainly will not be used in the final quality control procedure. In general, he should be a more competent and versatile man than the one who is to administer the SQC system, after it is installed.[12]

Leverage Powers of a Complete SQC Organization

Exceptional Advantages of SQC for the Larger Company

Although quality control is important to even the smallest size company, there should be pointed out some of the extra advantages that the installation of a complete SQC system can yield to a moderate or large size multidivision company with a central research laboratory. In this instance, the crew of experts for devising, installing, and initially operating SQC systems can be gathered together by the laboratory as permanent employees. The laboratory then becomes, in effect, the contractor for making SQC a going reality in each manufacturing division. In this phase of the laboratory's work its objective should be that of working itself out of a job as quickly as possible. It will take some time for the laboratory crew to go from plant to plant leaving practical working quality control processes behind it, but any method of installation that is very much swifter is likely to be infeasible. This is essentially the general program now under prosecution in The Carborundum Company which appears to be progressing satisfactorily.

Quality Control as a Line Responsibility and as a Staff Responsibility

If and when the expert crew has made the round of all the plants, is it then out of a job? Not by any means. The crew now consists not only of expert quality control engineers, but persons who are highly conversant with every phase of technology in the company's oper-

ations. A "brain trust" of similar quality could scarcely have been acquired at lesser cost, if that had been the objective.

The crew can now be broken up into three departments within the laboratory. The first would be a Process Quality Control Department consisting of a nucleus of one, two, or three experts to exercise staff supervision of all the SQC systems; give aid to the men who operate these systems in the more difficult phases of their work, or during changes in product lines; and do some research in devising special quality control techniques for the company. Note, however, that the line control of each process SQC system should rest squarely on the man responsible for manufacture in each division: the laboratory Process Quality Control Department should have only staff responsibilities, and these should be exercised through the laboratory director like his other staff responsibilities.

The Problem of Really Knowing Quality of Product

The second group would be Quality Assurance or Quality Assessment Department. It should be charged with seeing to it that outgoing quality is economic and competitive, and should be charged with surveillance of all specifications.

The economic implications of such a department are highly varied, large and important. Probably the best known group of this character is the Quality Assurance Department of the Bell Telephone Laboratories, which among its various other functions is an authoritative and unbiased umpire in the many dealings between the many members of the Bell System.[13] Let us consider some of the implications of a Quality Assurance Department.

In a multidivision company, the finished product of one or more divisions is the raw material of others. Thus, there are intra-company sales, as well as sales outside of the company. It naturally follows that disputes occur between the divisions. A consuming division will not only tend to demand of a vending division that it deliver a very high and perhaps unreasonable level of quality, but even blame defects in its own outgoing product on the character of the raw material supplied it by the vending division. In the absence of at least an adequate substitute for a quality assurance department, each respective division generally succeeds in establishing itself as the best quality judge in the company of products within its field. Company divisions are as much motivated by self-interest as individuals whose attitude was so well described in Thomas Carlyle's *Sartor Resartus* that I shall use Carlyle's words:

> "Now consider that we have the valuation of our own deserts ourselves, and what a fund of Self-conceit there is in each of us,—do you wonder that the balance should so often dip the wrong way and many a Blockhead cry: See there, what a payment; was ever worthy gentleman so used!—I tell thee, Blockhead, it all comes of thy Vanity; of what thou *fanciest* those same deserts of thine to be."

Without valid tangible data gathered by an agency that understands sampling, and without evaluation in a probability sense, the staff director of production is likely to yield in his ruling to the most positive and vociferous spokesman, when, as a matter of fact, the vending division does not know the cost of producing somewhat better quality, the consuming division does not know the correlation between quality of received raw material and quality of its outgoing product, and none of them know the economic levels of quality for the competitive markets with which they are concerned.

A quality assurance department should check on the quality level of all products of the company; be able to interpret quality in terms of cost; cooperate with the Operations Research Department or the Marketing Division *in determining the economic level of quality for each product of each division relative to the markets with which each is concerned;* and establish valid specifications for all products. Thus, the company can know how to manufacture at an optimum level of quality. Specifications for outgoing products that are under the custodianship of manufacture are almost invariably tinged with self-interest, and can scarcely be expected to reflect the best companywide viewpoint. This is a very large task and a very important one from the viewpoint of both the short-term and long-term welfare of the company. Note, however, that its functions can hardly be performed at all, unless the divisions operate under statistical quality control; and, even under these conditions, comparison of competitors' products with company products is less precise than comparison between company products, and more difficult.

Decisions Without Tears

The third group would be an Operations Research Department. Its primary responsibility is scientific bases for the decision-making process. At first glance, the practical engineer, the dynamic executive, and the canny business man, may look askance at bringing higher mathematics and concepts of statistical probability to the council table where grave and important matters of a business and technical nature are to be decided. There is no question that experienced good judgment is indispensable to good decisions. However, there is also no question that Operations Research, which was born with World War II as an aid in making decisions in tactics and strategy, has been so successful when applied to peace-time pursuits that its practitioners now form a large national society. Its success, like that of TV and automation, inheres in its making a highly technical mechanism amenable to simple operation for practical ends. The complexity of present-day business demands the orderly discipline of mathematics and the rationality of probability concepts in order to summarize facts, postulate the consequences of possible decisions, calculate the risks associated with and the probable costs of the consequences of decisions, and to select a decision that optimizes the conditions that are favorable to the decision maker.[14] The men who do the fact gathering, the summarizing of facts, and the calculation of probable results, should not only be competent in their scientific and engineering fields but also familiar with the company. The graduates of quality control are well suited to such work. If they but point to the optimum decision in one or two matters a year, such as whether or not a company should be acquired, a merger entered, or a new product line adopted, they will far more than pay for themselves.

Process SQC, A Fundamental to Company Health

Thus, it would seem that process quality control is almost a prerequisite for leadership in today's competitive markets. The company that does not have it and does not need it is rare. How far it should go in statistical quality control depends upon size, complexity, and various other considerations; but without process quality control as a fundamental basis it is difficult, if not impossible, to use efficiently the higher techniques. Hence, it is wise to initiate a well planned process control program under the sponsorship of top management, and evaluate the desirability of more advanced applications of statistical methods as the company's own peculiar system of quality control is evolved. A lesser measure involves grave risk of being outclassed in tomorrow's competitive markets.

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Top Management Decisions Made Easier Through the Effective Use of Quality Control*

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In order to set a frame of reference for this discussion, let's look back more than ten years ago to 1946 which was a year of decision for most companies in a number of important ways. First of all, that was the year most of us were setting up for the production of civilian goods at a rate exceeding our pre-war capacities. This involved more elaborate planning, production controls, and material controls in addition to the acquisition of more equipment and modern facilities. Of equal importance was the fact that during the war the science of controlling quality by statistical means had come into widespread industrial use. So an important challenge to top management at that time was controlling the quality of mass-produced goods by statistical methods.

Our first attempts at applying these new quality control techniques were made on our assembly lines. Looking back over ten years, those first simple range charts seem very crude. They were bolted to the factory walls and were used by the line inspectors as visual indicators of the dispersion in critical assembly operations. Measurements were taken hourly by quality control clerks. It was easy for the chief inspector on any assembly line to see at a glance whether his quality range for those critical operations was excessive. Those chief inspectors were educated and assisted in forming judgments by the quality control managers.

It was at this time—about ten years ago—that one of our cardinal operating policies was established.

*Presented at the annual training course in SQC sponsored by the Chicago Section, ASQC, in cooperation with the Chicago Association of Commerce and Industry.

In Whirlpool-Seeger our quality control managers have both the responsibility and the authority to stop any operation which is outside quality limits. On our assembly lines it is not uncommon for an inspector to issue an order "stop the line."

Perhaps at this point I should go back one step and explain that in all of our plants the quality control organization reports to top management. In both theory and practice the quality control groups are independent of the production line organization and are free from the pressures of meeting schedules. In other words, quality considerations are paramount and are placed ahead of sales schedules and customer demands.

Now, let us go back to that order "stop the line." The minute any assembly line is stopped, it is the duty of the line foremen to find out immediately from the quality control people the reason for the stoppage. In most cases, assembly line stoppages are due to poor workmanship on the part of one or more assemblers. The line foremen must quickly point out the defects to all concerned and take positive steps to prevent any recurrence. In addition, these foremen must check every machine on the assembly line to make certain that the necessary adjustments and repairs are made on each machine. Only after these positive steps are taken can the line be started again.

The time of stopping an assembly line, the time of starting, and the reason for the stoppage are all reported by the quality control people to top management at the end of every shift. It is through these reports that top management decisions regarding assembly departments are made easily, quickly, and fairly. It is possible by analyzing these reports to form judgments as to the work force, and the capabilities of assembly supervision. Furthermore, any consistent repetition of stoppages for the same defect frequently leads to changes in engineering design. Many times top management is able to determine that designs released by the engineering department simply do not lend themselves to normal manufacturing processes. So in the area of assembly, SQC is a real tool for management.

It was back in those days right after the war that another vital quality control measurement was established in our company, and this one, I believe, is unique. It is the measurement of the number of service calls made to homes of customers expressed as a ratio to the number of sales. Actually, we would never have been able to develop or use this measurement if it had not been for the wonderful cooperation given us by our largest customer, Sears, Roebuck and Company. Here is how this control works.

Sears have established a number of key stores as quality control points. These key stores are scattered all over the country. In each of these stores Sears servicemen keep a complete and accurate record of the reasons for every call that comes in from a customer on each of our products. At the end of every month these calls are totaled for all of the reasons that have been discovered. For example, all of the service calls that trace back to either the installation of, or the instructions covering, our machines are listed as Sears' responsibility. All other causes are listed as Whirlpool-Seeger's responsibility and these are totaled by part or assembly. In addition, each of these key stores reports total sales for each of our products at the end of every month. The Sears Service Department in Chicago combines the reports from the key stores and sends the collected data to our company's headquarters in St. Joseph, Mich. We, in turn, make a complete statistical analysis of these data and translate the findings to quality control charts.

Every month each of our top management men receives a package containing charts which show the service calls for each product that month, and also the number of service calls for the preceding three years. In addition, there are breakdown reports which show quality levels for every component and assembly. Any rise in the trend line of service calls means only one thing to each member of our top management team—that is, prompt and decisive action. As a matter of fact, this unique variation of statistical quality control is so sensitive that time after time we have been able to pin-point potential service headaches long before the men in our plants had any idea that we were headed for trouble. The net result is that we are able to make corrections and improve the performance of our products much faster than is generally believed to be possible.

There is a third vital area in which our top management decisions are made easier through effective use of quality control. That is the area of capital expenditures. Perhaps a very recent example will best illustrate the value of SQC in this field. By way of background, there has been a recent trend toward porcelain enameled finishes for home appliances. All-porcelain machines, even though they are expensive, seem to have taken the fancy of American housewives because they represent top quality. From a management standpoint, one of the problems created by this trend is the amount of capital investment required to build a new porcelain plant. Right now a modern, automated plant of this type with one large furnace and a large automatic pickler costs about $3,000,000. When it is realized that we are manufacturing home appliances in seven different divisions, there emerges some idea of the amount of money involved in satisfying our market for porcelain enameled machines at this time.

About a year ago, one of the seven divisions came into our company as the result of a merger. There was a first-class porcelain facility in this Division, but statistical quality control had never been applied in its operation. We decided to run an experiment and to go all-out in applying SQC to the operations in this plant, at the same time keeping an accurate measurement of the quality levels before and the quality levels after the installation. We were surprised to learn that prior to SQC the total pieces rejected at eighteen different control points was 44 percent of the total pieces started through that plant. After SQC the percentage of rejects at these same control points had dropped from 44 percent to 15 percent. Obviously, the capacity of that plant had been tremendously increased by dropping "re-ops" 29 percent. Whereas the plant had formerly had difficulty in meeting a schedule of 1,000 tops per day, it can now produce 2,300 tops per day very handily.

When we translated that increase in capacity into plant and equipment, top management found that capital expenditures which we were certain we would have to make in 1957 could readily be deferred until 1958, thanks to statistical quality control!

There is one more very dramatic example of decision-making through effective use of quality control. It has to do with acceptance sampling of incoming shipments. Early in the game we were guided in this area by the joint Army-Navy sampling plans developed during the war. We used JAN tables #1, #2A and #2B. The results were so significant that we have constantly expanded and refined our acceptance

sampling techniques since. Right now we are applying the sampling tables known as MIL-STD-105A.

To illustrate the value of this application in making top management decisions, consider our experience with timer switches. These timers that control the cycling of our automatic washers and automatic dryers are really the heart of the machines. We have always purchased timers from specialists in the electrical controls field.

About two years ago the trend lines for timer-switch service calls, as reported by the key Sears stores, pointed sharply upward. We promptly set up checking procedures in the incoming inspection departments in accordance with our acceptance sampling tables. Quality control charts were installed and these showed that the percentage of defective timers being received at our docks closely paralleled the percentage of defective timers reported from the field. At that point, all of our timer-switch vendors were fully advised of our findings and were asked to set up quality controls in their own plants that would be identical with ours. Within one year the percentage of defective timers received by our plants dropped 80 percent. In the succeeding year, there was a further drop of 14 percent. Right now our quality control people have hopes of dropping the percentage of defective timers we receive below ½ of 1 percent.

There is just one further step we have taken in this field of acceptance sampling. We have now worked out certification agreements with a number of our suppliers. These agreements provide that statistical quality controls will be used by the suppliers, and that each lot of parts they send in to us will be certified to be within definite limits of acceptability.

We do not check such parts, but send them directly to the assembly lines. Actually, this whole program of acceptance sampling and vendor certification has been extremely helpful to top management in choosing our sources of supply and in firming up the fine relationships which we enjoy with all of our vendors.

Four examples have been cited showing how top management decisions are made easier through effective use of quality controls. The four examples covered were quality improvements on assembly lines, better service in customers' homes, reductions in capital requirements, and better supplier relationships. No delineation has been made of the value of SQC in upgrading the quality of punch press stampings or screw machine parts. That entire area is really a subject which should be treated separately and in detail.

Perhaps the convictions which we in Whirlpool-Seeger have about the effective use of quality controls can best be summed up in this way: we are expanding our investment in statistical quality control procedures because we are certain that they are the surest way of raising the quality levels of the products which we want to sell in increasing volume to the home-owners of America. We feel that we do not have any better investment than the one we are making in SQC. We can strongly recommend it.

The Relation Between The Engineer and The Statistician

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Increasing complexity of research, development, and production problems demands new approaches, new tools, new methods of attack, lest ever-mounting complications slow or strangle scientific progress. These difficulties, generated by increased sophistication in scientific development and by the accelerated pace demanded by technical, economic, and military competition, have caused the engineer* to appraise, with becoming modesty, his own powers in his chosen field.

Time was when knowledge was so limited that one man could, almost literally, "know it all." The grasp of a Newton or a da Vinci over and in advance of the physical sciences of their day cannot possibly be approached by any one man over the vastly larger scope of science today. Yet this is required to permit significant progress today. How can we do it? We no longer expect great advances in science from the unaided efforts of the individual. No, science today advances mainly through teamwork, frequently by nationwide coordination of many teams all operating in the same field of interest. The team concept is reflected with increasing frequency in modern research, development, and production organizations. Teams comprise groups of scientists or technologists who specialize in the disciplines pertinent to the problem.

Increasingly we find that one or more of the team is a statistician. The statistician is not new to the field of

*As used in this article, the terms "engineering" and "engineer" refer broadly to the physical sciences, related application technologies, and practitioners in these fields. It is quite possible that relationships between statisticians and experts in subject matter fields other than "engineering" could profitably parallel lines suggested herein.

engineering; Charles Darwin brought data evaluation problems to the mathematician, Galton, for resolution. But the statistician has not really been associated with engineering problems on a scale commensurate with his ability to contribute, though a gratifying start has been made in applying the work of such pioneers as "Student", Pearson, Fisher, and Shewhart.

At first, and to this day, the engineer appeared slow to recognize the value of expert statistical guidance. Some statisticians have regarded this fancied weakness with some vehemence and self-righteous indignation, but if technology has not used statistics to its full potential, the fault is neither the engineer's nor the statistician's alone. Perhaps most of it is due to human frailty.

The problem is how to alert more of the scientific fraternity to the necessity for the team approach—in this case, the need for association of engineer and statistician. The statistician has a contribution to make in technology; it is up to him to "advertise" and "sell" it. In this, the statistician has been somewhat of a failure. In general, the statistician has not bridged the semantic and technical gap between himself and the engineer. Statisticians who publish texts intended to popularize or spread the use of statistics among engineers, have been derided privately for writing "cook books" pandering to the low tastes of the statistically illiterate. Such texts frequently open with a promise that only a modicum of mathematical background is required and then belie the statement in the next few pages, in line with the familiar usage in mathematical texts wherein an extremely complicated expression descends to a completely unlike formulation through the phrase "From which it is easy to see that:", or more simply "Obviously, therefore:". Where engineers turn statisticians and publish papers in technical journals, intending to popularize and illustrate the use of statistics by engineers, the publications all too frequently leave the reader cold or frustrated. Perhaps such papers should first pass a critique by disinterested and uninformed engineers similar to the legendary stupid officers (no offense intended) who make apologetic appearance on the staffs of all famous military leaders as critical proving grounds for well-written battle commands.

Even when the need for cooperation between statistician and engineer is established, long-lived difficulties can be generated by the manner in which the relation between the two develops. Statisticians tend to overlook the fact that, while he may not have been particularly efficient at it, the engineer has actually formulated experiments, accumulated and evaluated data since his first day as a student. It is not surprising, therefore, that he feels reasonably competent in these fields. He views with complacency the generally satisfactory progress which science and technology have made with apparently little help from the statistician. But, though he has done quite well without statistics up to now, our engineer wants to be perfectly fair, broad-minded, and forward-looking. He does recall hearing about long-hair statisticians who can set up tests and evaluate the results better than engineers. Well, maybe . . . . . , in very complicated cases. "Tell you what; if I run into a really tough one where I can't find the best way, I'll call that statistician for advice—what did you say his name was?"

As the situation developed, the engineer came to regard the statistician as a consultant. Now, the title may be one of dignity but the usage is occasionally less gratifying. Normally a consultant's advice is accepted and used by the individual seeking these services. Occasionally, however, procedures recommended by a statistician are modified or even ignored by the engineer. There is little point in berating the engineer who refuses to accept the statistician's suggestions; this difficulty is relatively trivial.

A more important problem by far is generated when the organization is such that the initiative as to the need for statistical consultation rests with the engineer. In other words, the statistician is consulted only when the engineer considers it necessary. Where this occurs, it is a grave weakness; the decision is left to the man least competent to make it. Until the statistician earns the engineer's full confidence, the engineer tends to regard the statistician somewhat as he would a child prodigy—interesting and clever in his way but not to be completely trusted with any real problem. So it is not surprising that the engineer frequently balks at, rejects, or modifies recommended statistical procedures. In the case of a test design this may lead to failure of the test, mutual recriminations, and distrust.

In this uncomfortable situation the statistician may take refuge in certain dodges, which evade the issues and tend to entrench him more firmly in the "ivory tower" which the engineer considers to be the statistician's normal habitat. Some statisticians insist that they will refuse to operate upon data generated in tests they did not design, nor will they stir if a test design they specified is modified in any way. It is hard to believe that such an adamant stand is actually maintained in practice, but it is loudly advocated. Of course, in adopting this position, the statistician may lose golden opportunities to point out the havoc wrought in testing programs by poor test designs and then follow up with constructive recommendations.

Other statisticians suggest that the consultant confine himself solely to statistical aspects of the problem and avoid any discussion or speculation in the (non-statistical) technical subject matter phase. It is equally dubious that in any practical situation this sterile attitude is maintained. Certainly, the statistician should refrain from pretending to authority in a field not his own, but this should not prevent him from making suggestions as to the possible engineering meaning of his findings. There can be no objection to the statistician venturing into the technical field. However, final decision as to the engineering significance of statistical findings must be made by the engineer, except that such decision must not controvert the data as statistically evaluated. Equally, there is no harm in the engineer offering comments to the statistician, particularly as regards the technical and economic realism of his statistical designs, provided it is understood that final decision in this case rests with the statistician.

The statistician must be receptive to criticism which indicates that his test design is too expensive, complicated, or time-consuming. He must be sure that the work projected in his test design is not more than is required to achieve the objectives set by the engineer. Many statisticians do not realize that running a factor once at each of two levels almost always involves much more work than running the factor twice at the same level. They count only the number of determinations to be made, not the operational changes for each determination.

The statistician should not accept in wordless resignation unilateral changes by the engineer in statistical test designs or data evaluation. Neither should the engineer surrender his birthright in fields (such as sampling and quality control) which are statistical in theory but engineering in application. The statistician

must not sulk in his tower as Achilles in his tent, nor should the engineer be silent when given a mathematical pattern devoid of engineering sense. On the contrary, given sufficient cause, let each scream to the heavens, for from honest controversy truth and understanding may emerge. The plain fact is that close cooperation is essential between the statistician and the engineer. Each must strive to explain to the other his needs or findings in the detail required for complete understanding by both of the problem, data, conclusions, and recommendations involved. The engineer has too often refused to make the mental effort required to comprehend the service the statistician can provide. The statistician has too often considered the engineer's problem an opportunity to make a display of erudition rather than a contribution, confounding himself as much as he does the engineer.

Many of the faults properly laid at the statistician's door result from his ignorance of or lack of interest in the engineering subject matter field involved. At the same time some of the blame must be accepted by the engineer who, when faced by some statistician's brainstorm, fails to demand a clear explanation to demonstrate the value or utility of the procedure recommended by the statistician. This weakness merely encourages the statistician to commit additional sins against the engineer.

The need of the statistician to understand the engineering subject matter with which he will deal can best be appreciated through actual experience. Statisticians who are most competent in the application of statistics to technology almost invariably possess considerable educational accomplishment and experience directly in the engineering field. Very rarely do we find a top-notch statistician active in the engineering field who has had no previous formal engineering training. In this regard, the technological statistician is very much like a patent lawyer who is most successful when he holds an engineering degree, usually acquired prior to his legal training. It is not held that a statistician, as such, cannot eventually become very useful in the engineering field; it is simply much more difficult for the statistician to turn engineer than it is for the engineer to turn statistician.

There are many examples from actual practice wherein statistician and engineer contribute to the solution of pressing technical problems through cooperative effort in a manner which can best be described as interpenetration of the sciences involved. A single example will suffice to show clearly how interplay of intelligences operating in both fields, frequently in fine disregard of purist attitudes commonly adopted, can illuminate problem areas only dimly realized and effect important advances in the technology concerned.

The case in point started during a "coffee break" when the statistician heard a chance remark made by a production engineer that a certain arsenal found it easy to manufacture Widgit X* to prescribed quality requirements during the winter, but it was difficult to meet these requirements during the summer. This interested the statistician; it is strange that most of the production engineers knew about this but, after some trivial, half-hearted attempts at investigation, they gave it up as a bad job.

In this instance, however, the statistician provoked further discussions, later broadened to include their respective superiors. It was decided to investigate the truth of this assertion and, if true, to try to discover why we had trouble during the summer but not during the winter. At the time, the Widgit was no longer being manufactured, so that only information which could be gleaned from existing inspection and production engineering reports would be available as grist for the statistician's mill. Were the statistician a purist, he might have begged off on the plea that the data were not generated in accordance with a statistical test design, that the body of data might be incomplete in significant areas, that it was too voluminous, etc. In short, he had every excuse to refuse the job. Instead, he welcomed the opportunity. His study immediately revealed a definite relation between average quality at the time of acceptance test and the date of manufacture. Further, he discovered that almost all malfunctions occurring during test were caused by failure of a pellet pressed from a mixture of two simple chemicals.

At this stage of the investigation, the statistician could do no more. He discussed his findings with the engineer, pointing out that it was obviously not the date which influenced Widgit quality but it was something associated with the date which, for technical reasons, would have an effect upon the Widgit. Two possibilities were offered by the engineer: temperature and humidity. The statistician explained to the engineer that, if temperature and humidity were related to date, both factors would undoubtedly be found to correlate statistically with Widgit quality. Since it had already been shown that date was related to quality, it would obviously follow that whatever characteristic related to date the engineer chose, it would also be found correlated with quality. (In making these statements, the statistician had begun to enter the field of engineering to explain to the engineer the statistical consequences of the engineer's decision.)

For chemical reasons, the engineer decided that the significant characteristic was probably relative humidity. In reply to questions put by the statistician, the engineer allowed that he expected the correlation between relative humidity and functionability to be high and inverse, rather than direct and low. No direct information was available as to the relative humidity at the Widgit assembly line; but by making suitable assumptions, it was possible for the engineer to draw a chart allowing calculation of humidity at the assembly points from temperature and outdoors ambient relative humidity.

At this point purists would have washed their statistical hands of the matter. No one pretended that this chart represented data which were generated as part of a statistical test design. There was some question as to the full extent of its validity; no way existed to answer such question with authority. Nevertheless, based upon this chart, a correlation was made between calculated relative humidity and Widgit quality expressed as percent effective. Fortunately, what we lacked in precision of data was more than made up for by volume. As expected, relative humidity was found to be correlated inversely with quality with very high statistical significance but the coefficient of correlation was disappointingly low, approximately −0.3. Were it not for the fact that the sample size ranged in the thousands, this correlation might never have become evident.

The statistician reported his findings to the engineer. Again he reminded the engineer that this relation between relative humidity and quality merely reflected the relation between date and quality; further, the

*The identity of Widgit X, its components, and the actual data to which we refer are not revealed for military reasons. However, it can be said that Widgit X was of utmost importance during World War II.

actual correlation found, while highly significant statistically, was very much lower than the engineer had predicted. Neither the engineer nor the statistician could explain this. The engineer felt this might possibly have been caused by lack of truly precise humidity data; the statistician felt that it might have been due to the fact that the correlation was calculated as linear while it might actually have been curvilinear. It is interesting that each sought the explanation of the discrepancy in his own field—the engineer concerned himself with the humidity problem, the statistician with the question of linearity. Little could be done about the former, but when the statistician ran a test for linearity he made the key discovery.

The correlation study had been based on grouped data. In examining the data for linearity, the statistician discovered that the negative correlation between quality and humidity was extremely high at low humidities. It became worse, though still significant, as relative humidity increased, but, for some strange reason, above 55 percent RH there was no significant correlation between quality and humidity. Now it was easy to understand why the over-all correlation, which encompassed all classes of humidity, was lower than the engineer's expectations. But to explain why the correlation ceased above 55 percent RH was beyond the statistician.

At this point, knowing these facts, it would be interesting for each to ask himself, were he the statistician, what he would do. We have found quality to be related to date and, thereby, inversely related to relative humidity. The relationship was excellent at low humidities, grew worse at higher humidities, and was completely lost above 55 percent RH. We knew that practically all malfunctions were due to failure of a pressed pellet of a mixture of two simple chemicals. These findings seemed to have very little practical significance. Those of us who are engineers might well question what further steps could be taken.

It is at this point that the truly competent statistician must rise to the occasion. He must use his knowledge of the engineering subject matter, however limited, to furnish guesses, wild guesses if need be, to catalyze the engineer's thoughts and help him determine why the correlation ceases above 55 percent RH. Above all, it was critical that the statistician recognize intuitively that the answer to this question was very probably the engineering crux of the problem. Certainly no ordinary engineer would, on his own, be interested in what appeared to be purely a statistical freak, let alone divine that it had any engineering importance.

In this case the statistician hazarded the guess that one or both of the chemicals, or perhaps an impurity therein, was characterized by some significant property immediately associated with the figure 55 percent RH, such that ambient humidities below 55 percent RH had one effect on pellet functioning while humidities above that figure had a different, probably opposite, effect. The question was: what was the characteristic property and what chemical material was involved? This question was the spark that ignited the engineer's intelligence. The physical characteristic involved was plainly the equilibrium relative humidity and the difficulty was pinned on a certain chemical impurity in one of the chemical constituents of the pellet. Upon searching the literature, it was found that the equilibrium relative humidity of this impurity at room temperature was 54 percent. Now the phenomenon was completely explainable chemically, physically and statistically.

It became perfectly clear that to eliminate the variation in production quality caused by humidity, one of three courses would have to be taken: use chemical constituents free of impurity, or use the impure constituent but control humidity at the assembly points and within the Widgit container, or develop another component impervious to moisture.

We didn't stop here. These findings were preliminary to even more important studies and findings with respect to the remaining stock of Widgits not exhausted by use in war. Joint studies by statistician and engineer enabled us to estimate with utmost precision the useful serviceable life of the Widgits remaining in storage. Considering what we discovered in this and succeeding studies in connection with the Widgits in storage, it is not too much to say that they comprised the most important single group of statistical and mathematical studies carried on within our technical service in the past ten years. We learned how to manufacture better Widgits and what to expect with respect to their storage life. We were also able to develop a basic theory of lotting to insure homogeneity in production. It gave us the insight to develop the theory and practice of grand lotting in Chemical Corps surveillance. But perhaps most important of all, it laid the foundation for a proper relation between the statistician and the engineer at Chemical Corps Materiel Command.

Since that time, it has been understood that the top echelon of our Quality Assurance engineers require a good working knowledge of technological statistics and our top echelon of statisticians must have engineering degrees. Other professional personnel in the Quality Assurance Directorate, who may have little or no training in one of the two fields, are motivated to strengthen themselves in their weak area, for this is the road to advancement. At the same time, they are kept in closest contact with their counterparts in the opposite field so that all operate in accordance with the doctrine that each man makes final decision in connection with problems in his own area and offers such comments and suggestions to the other area as he may deem helpful. In any important matter subordinates bring their findings to their superiors who can speak with almost equal authority in either subject matter field.

The important organizational factor, probably unique in character, is that this relation of engineer and statistician is *enforced*. The engineer is not left to decide for himself whether he need consult with the statistician on data evaluation, test design, sampling, quality prediction, and the like. Nor is the statistician permitted to publish engineering conclusions in his studies unless these are acceptable to the responsible engineer.

The organization requires engineer and statistician to work together as coequal partners in the solution of quality assurance problems. Since both the engineering and the statistical groups are charged with responsibilities which insure enforced continual contact in most problem areas, one may well wonder whether this might not lead to jurisdictional disputes. We can only reply that, in over ten years of operation, no such dispute has ever arisen. Though, in any given field of interest such as sampling, both engineering and statistical considerations are seemingly inextricably intertwined, the principles of the organization form the thin, sharp line of demarcation: namely, every man makes final decision in his own professional field and has the right and is encouraged to offer suggestions, comments, and make all the mistakes he wants in the other man's field and with impunity, since responsibility for final decision as to acceptability of these comments rests with his teammate in the other professional field. It works. Try it.

FIND CAUSE .. ELIMINATE IT

Make It Right The First Time

LEON BASS

General Electric Company, Cincinnati, Ohio

Introduction

Early in our country's history Benjamin Franklin recognized the value of preventing trouble before it started when he wrote in Poor Richard's Almanac, "a stitch in time saves nine." Old Ben may not have been the first to make such an observation, but the fact that he made it 200 years ago illustrates that the principle has stood the test of time.

Today this idea is followed in many fields to save thousands of lives which would be lost in accidents and illness, to improve the health of thousands of people who would be condemned to live in pain or incapacity, and to save millions of dollars worth of property from loss due to fire and other catastrophes. This principle applies in the field of quality control. Basically, quality control employs the same method used in the other fields of prevention. Very simply stated, it is this—"Find the cause and then eliminate it."

The purpose of this article will be to expand a bit on this thought, particularly to relate it to those quality factors which have important effects on sales, and to present a few examples of defect prevention from General Electric's Jet Engine Department.

Factors That Affect Sales

When a salesman is selling a product he is faced with two problems, each of which is equally important to the continued prosperity of his company. He first must persuade a customer to buy the product. There are many factors that combine to produce these first sales. The four which probably are the most important are the *sales* effort which is applied, the *price* in comparison with competitors' prices, the *availability* so that the customer may have the product when he needs it, and the *reputation* of the vendor, which is a measure of the trust that a potential customer will place in the company.

After having landed the first order and delivered the product, the salesman wants to enjoy repeat orders. This means that he must sell the product and company again, with the purpose of persuading the customer to keep on buying. The most important factors at this time are the *quality of conformance* and *appearance* of the product already supplied, the *technical excellence* and *utility* that the design has demonstrated in use, the *value* of the product when all economic factors are considered, and the willingness to be of *service* that has been displayed in connection with the customer's use and maintenance of the product.

Defect prevention contributes much toward both getting the first order, and influencing repeat orders. For example, the *price* of the product is affected because the prevention of defects lowers the overall cost, and this effect can be sizable, as will be demonstrated later. The company's *reputation* is built strongly on the *continued* quality of product which is possible only with a smoothly functioning defect prevention program.

There is no need to dwell on the importance of lack of defects in determining the company's performance in the areas of conformance quality and appearance quality. All of the examples which will be described show how defect prevention can be of great advantage over defect rejection programs.

The effect of defect prevention on the overall value of the product to the buyer may seem to be nebulous at first blush, but it is based on hard economic consideration. Quality that is controlled by a defect prevention program produces products in which most of the defectives are borderline cases rather than "flyers," which are far outside of specification. As a result, they do not necessitate having to interrupt the steady flow of production in a customer's plant in order to sort out bad material or loosen up a jammed machine. If the customer is a direct consumer,

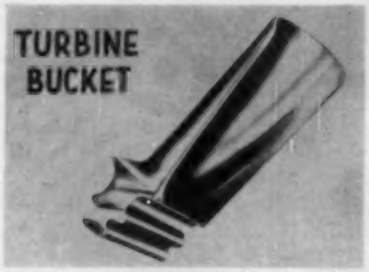


Figure 1

he is likely to accept the defect as a slight imperfection instead of "blowing his top" about the inferior merchandise which was sold him for good product. The costs of these situations are not readily accountable, but they are important factors in the overall value of the product that is sold.

Sources of Defects and Defect Prevention

STEP 1

In a discussion of defect prevention or trouble shooting one often hears the phrase "scientific method." This is often described in from two to ten steps. In the Jet Engine Dept., it is generally thought of in terms of three steps. The first is to survey the area in question to determine the extent of the trouble and to gather the information which will be pertinent to the discovery of the nature of the trouble. This information may be written or verbal, formal or informal, statistical or non-statistical, and must be gathered with the possible sources of defects kept in mind. These sources are sometimes described as the 5 M's—men, machines, methods, materials, and management. A few items that the trouble shooter looks for among these general classifications are:

1. Men—Has the operator been properly instructed so that he can do a quality job? Does he really know what a good quality item is when he sees one?
2. Machines—Was the job set up using proper tools in good condition? Has the machine the inherent ability to do the job (machine capability)?
3. Methods—Are the planned methods suitable for the job being done? Are they being followed? Is proper control of quality being exerted?
4. Materials—Is the proper material being used and is it of good quality?
5. Management—Has the importance and economic value of good quality to the company been sold to every level from top management to the operator? This is probably the greatest cause of carelessness on the part of operator or inspector. Is the operator aiming at the middle of the tolerance band as he should be, or is the production of defects which can be reworked to spec excused?

STEP 2

After the survey is made and the information is collected, it must be analyzed. When it was indicated that the information may be of all types, it was not meant to imply that all of these types are equally good. Statistical methods of analysis often are so much more powerful than non-statistical methods that wherever possible the survey should be in terms of control charts, frequency distributions, designed experiments, and other forms which can readily be analyzed by these techniques. When statistics cannot be used, more often than not the investigator must form his conclusions from inadequate information and he may have too little assurance that his answers are the right ones.

STEP 3

After reaching a conclusion concerning which of the possible sources of defects are the causes of the difficulty, the third step is to take action. This is the step which actually prevents defects, the first two are guidance steps to make sure action is taken in the proper area. The action must be constructive and must be taken with the attitude of assisting the manufacturing unit in doing a good job. The "big club" philosophy has little place here, because the real corrective action usually must be taken by the producer of the product and not by the inspector.

Jet Engine Department Operations

Before some examples to illustrate the sales advantages of making it right the first time are cited, perhaps an explanation of the manufacturing operations in the Jet Engine Department is in order. In the first place, this Department has the responsibility for *designing* "production jet engines." This does not include the production of jet engines in large quantities. The production of the jet engines is accomplished in another department also located at Cincinnati. The manufacturing that is done is essentially the manufacture of engineering and test models of designs in order to determine their characteristics and develop satisfactory production drawings. Hence it can be expected that when production, in J.E.D. terminology, of a part for a new engine is begun, it may well be the first time this part has ever been produced; it may even be the first time that the particular alloy that is used has been worked. It is expected, therefore, that problems will be many and varied. It can be expected that, by the time enough of any one configuration has been produced to learn how to make

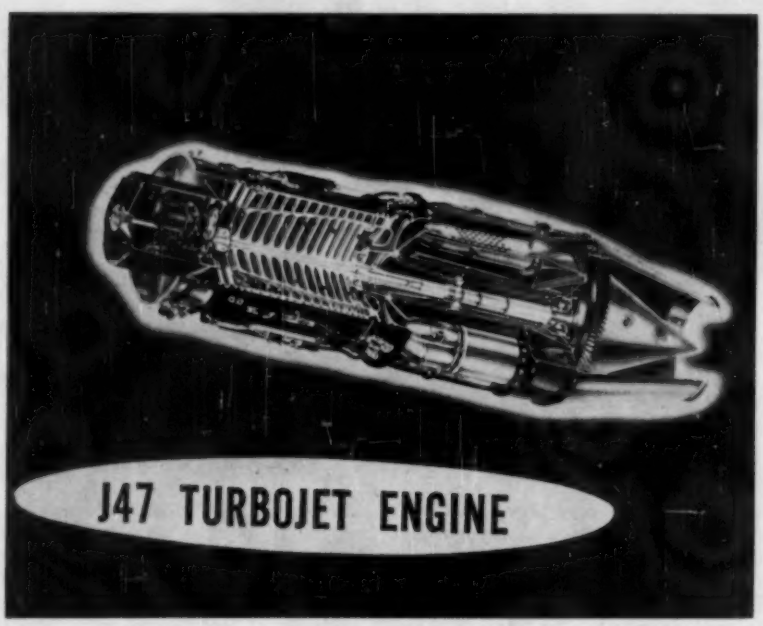


Figure 2

it, the manufacturing group will soon be confronted with a new design and in a sense have to start all over again. The short-time or job-shop nature of the operation also makes it imperative that control of production to prevent the manufacture of defects is achieved as quickly as possible. In other words, make it right the first time has perhaps more significance in this operation than might at first be suspected.

In setting up a defect prevention program, it has been indicated that the use of statistical methods has a distinct advantage. This, however, does not mean that these methods must be difficult or complex. Often extremely simple techniques will allow great improvements to be made in a program. The following applications will demonstrate this point. The particular part that will be mentioned most is the turbine bucket (See Fig. 1). Don't expect this part to show any resemblance to the "old oaken bucket." It looks more like a convex shaped blade and it has complicated contours. It has very few, if any, plane surfaces; in some instances it is machined all over; some of the contours are comparatively intricate. The tolerances are very tight.

To those not closely connected with the jet engine business, it might be well to explain the location and function of the turbine bucket. As a part of the turbine wheel, the turbine buckets scoop up a portion of the jet blast gases as they rush by, turning the turbine wheel. The turbine wheel turns the compressor to pack more air into the combustion chambers. A portion of this power is transmitted to miscellaneous engine accessories. In the cutaway illustration of the J47 (Figure 2), the location of the turbine wheel in relation to the other components that go to make up a jet engine is shown. As can be seen, the turbine bucket, although small, is a vital part of the jet engine, and any defects in this area could seriously impair engine efficiency.

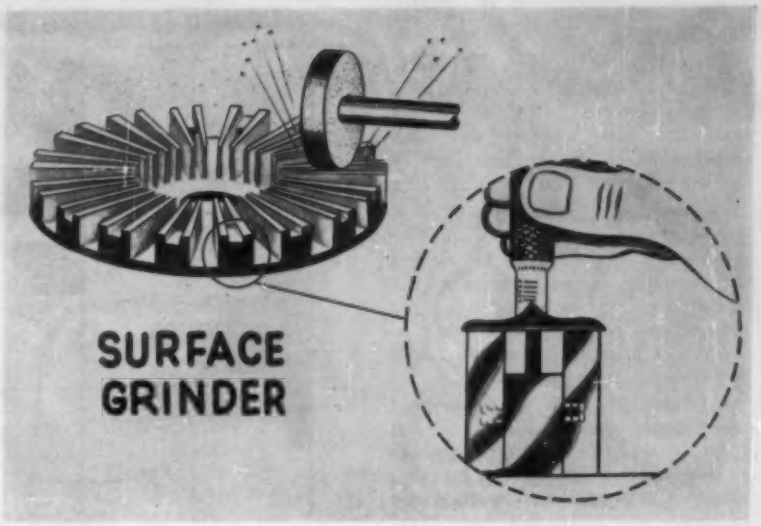


Figure 4

Example #1

As the first example in discussing defect prevention applications consider a comparatively simple operation—that of drilling and reaming two small holes in the shank section of the bucket. This is a case in which a fixture is made to position the bucket properly, a small drill is run through and then followed with a reamer. It was found, on investigation, that the initial production on this job was yielding too many defects (See Fig. 3). The holes were predominantly running oversize. The next logical step was to follow a few parts in their *order of production* through the operation and it was here that it was discovered that as the operation progressed and a reamer was used, there was a drift or tendency for the holes to get larger (Fig. 3). In checking back through the planning of this job, it was found that the planner had apparently expected that the hole size would get smaller as the reamer was used. He anticipated that the reamer would wear and its diameter would be reduced so that the hole size would go down with use. So, he had specified for this operation a reamer whose size was above the center of the specification. Actually as the reamer was used, it became dull and a pile up of material ahead of the cutting edge produced a larger hole. As a result of the increase instead of decrease in hole size, a comparatively new

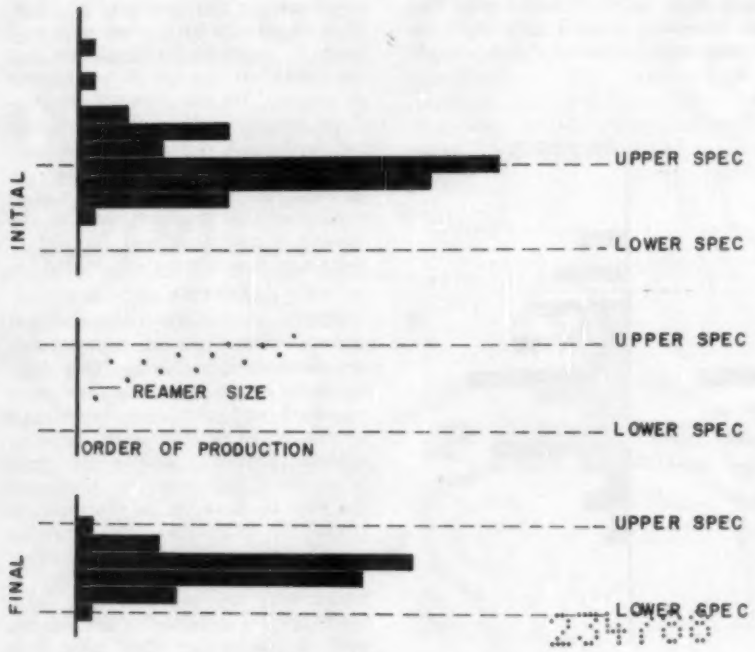


Figure 3—Histograms of the ID from the Reaming Operation

reamer was producing pieces that were too large.

As usual, once the facts are known a relatively simple analysis shows the right direction to follow. In this case, the basic reamer size was changed to be in the low part of the specification and thus allow a little room for change. A simple $\bar{X}$ and R control chart was set up. The operator was then able to control the changing of the reamers at the proper time. This brought the job into control so that the number of defectives produced was essentially reduced to zero (Fig. 3).

Interestingly this improvement had a double-barreled effect. It not only reduced the number of defects at this stage of the process, but also helped a subsequent stage discussed in Example #2. In this stage these holes are used as locators for a grinding operation, so that holes on the high side of the distribution actually increased the spread of the grinding and made that characteristic more difficult to control within the specification limits. Eliminating the reaming problem reduced this portion of the spread, but when the operation was investigated, it was found to be in further trouble.

Example #2

This next operation was a surface grind which used the two reamed holes to locate the part on a multi-station holding fixture (Figure 4). The normal inspection data showed that the specification was not being met in all cases. Figure 5 shows how the dimensions varied. It can be noted that the spread is too large and the process seems to be shifting its average value.

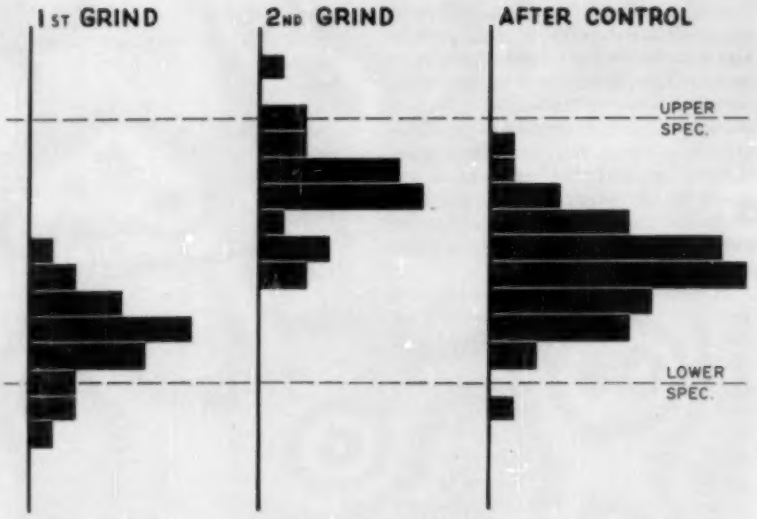


Figure 6—Histograms of Lots by Grind Showing Inherent Capability of Surface Grinding Operation

When the details were examined it was found that twenty-four parts were ground on one side at one time in a multi-station fixture. The machine operator used a depth micrometer to measure from the ground surface down to a spot on the fixture to determine when he had reached the correct dimension. It was discovered that he did not use the same station to make his measurement each time. Also, it was found that he generally ground only until his measurement showed that his depth of grind was just within the high side of the tolerance.

After the data was grouped by grind it could be seen that (Fig. 6) the *within-grind spread* would just about meet the tolerance but that the between-grind shift was causing the poor performance. Again the solution was relatively simple. First, a particular fixture to be consistently used by the operator to determine the depth of the cut was selected. In addition, the operator was given a ± half-thousandth limit about the center of the specification as the tolerance on the depth of the cut. This required a little more care and time in making the final cut but otherwise no change in equipment or process. He was then able to produce satisfactorily with practically no trouble. A reduction of 80 percent in defects was accomplished. In addition, the process average was so controlled that the likelihood of obtaining a part that was far out of tolerance was almost eliminated.

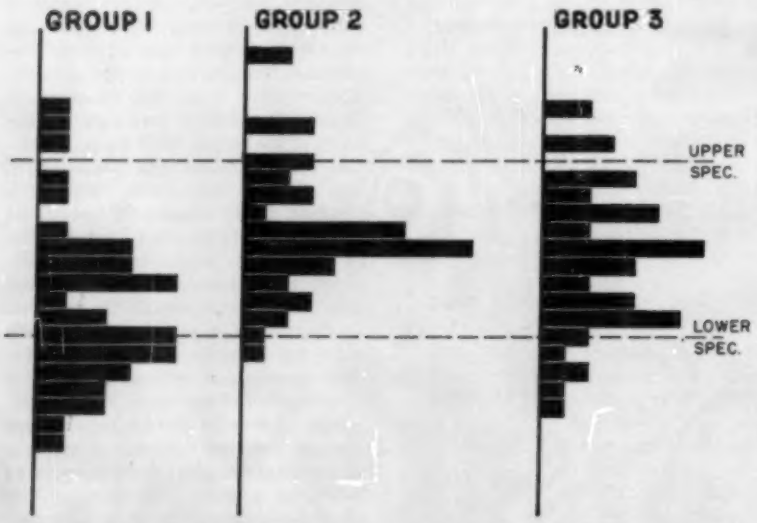


Figure 5—Typical Histograms of Mixed Lots from the Surface Grinding Operation

Example #3

The dovetail of the turbine bucket is, of course, one of the difficult manufacturing problems. This difficulty is due to the close tolerances required and the complex nature of the contours that must be generated. Figure 7 shows the type of contour that must be produced. As can be seen, it is symmetrical about the centerline. The drawing specifies the limits of the dimensions that are indicated. The operator is faced with the problem of closely controlling a number of dimensions and relationships. The machining method is a grinding process. In this

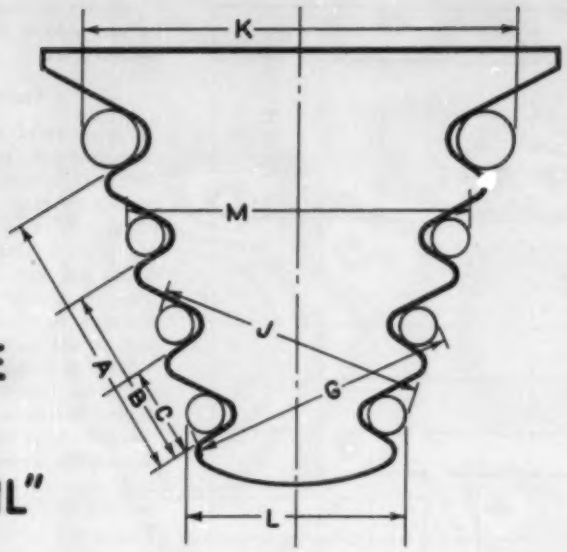


Figure 7

operation a Thompson contour grinder is used. This is a double-wheeled grinding machine that grinds both sides simultaneously. The basic contour is dressed into one wheel with a diamond point cam-controlled dresser. Using this dressed wheel this contour is ground into a steel crush roll. Both wheels are then crushed against this roll to generate the same contour on each wheel. When the bucket is ground it is held in a shuttle box and passed between the two rotating contoured grinding wheels as the wheels are moved toward each other. (See Fig. 8).

The initial study of the performance of this operation showed that specifications for some of the dimensions on practically all of the buckets were not being met. When considering that in this case 12 inspection points were produced, a ten percent probability of each being defective means that each part can be expected on the average to have more than one defect. Using these data and knowing the order of production, a machine capability analysis (using average range as an estimate of variability) was made. This study indicated that the machine was basically capable of meeting each of the requirements but that they were not being met in all cases largely because of incorrect machine setup, adjustment, and control. For instance, the relative location of the two dovetail sides is largely a function of the angular positioning of the axis of the crush roll. The thickness of the dovetail is determined by the operation of the machine piece-to-piece. The detailed contour of the dovetail within a side, is, of course, a function of the contour of the grinding wheel.

By following all of the dimensions in the order of production and noting when and what corrections or changes were made, it was possible to adjust the machine setup, that is, contour dresser, crush roll axis, etc., so that the dimensions that were generated were on the average approximately at the center of the specification. The operator was given an X chart of those dimensions that were largely controlled by the piece-to-piece operation of the machine. This enabled him to control the operation of the machine and maintain those dimensions within specification limts. Part of the data on the X chart also indicated to him when it was necessary to recrush or redress the grinding wheels. Immediately following any major change, all of the dimensions of the dovetail were rechecked. After the machine adjustment was accomplished and the procedure was initiated, the specification was met in approximately 95 percent of the parts that were ground. (See Fig. 9). In this way with a minimum of process inspection and data plotting, it was found that the output of this machine could be adequately controlled. In fact, one of the most critical dimensions on the part, the pressure face dimension, holds so closely that it is not checked on all parts—it is sample inspected for final acceptance.

Example #4

It was stated earlier that J.E.D. manufacturing is essentially model shop manufacturing and as such there is sometimes a need to do things that the shop may not really be set up to do. In one instance recently, they were asked to make a small part with an outside diameter having a tolerance spread of 0.0002 inch. No centerless grinding equipment was available and there was not sufficient time to send the parts to an outside vendor.

In a trial run on the most suitable equipment, it was estimated from a simple statistical analysis that the best that could be done would be a 0.0004 inch tolerance spread. This meant a high defect level and 100 percent sorting. Possibly the engineer could be made to

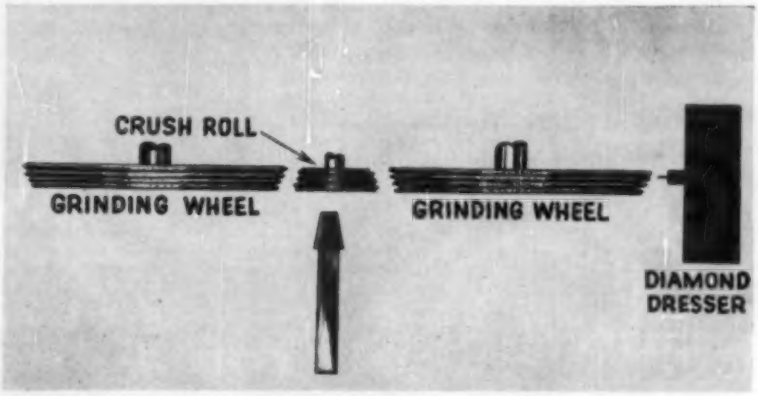


Figure 8—Contour Grinder

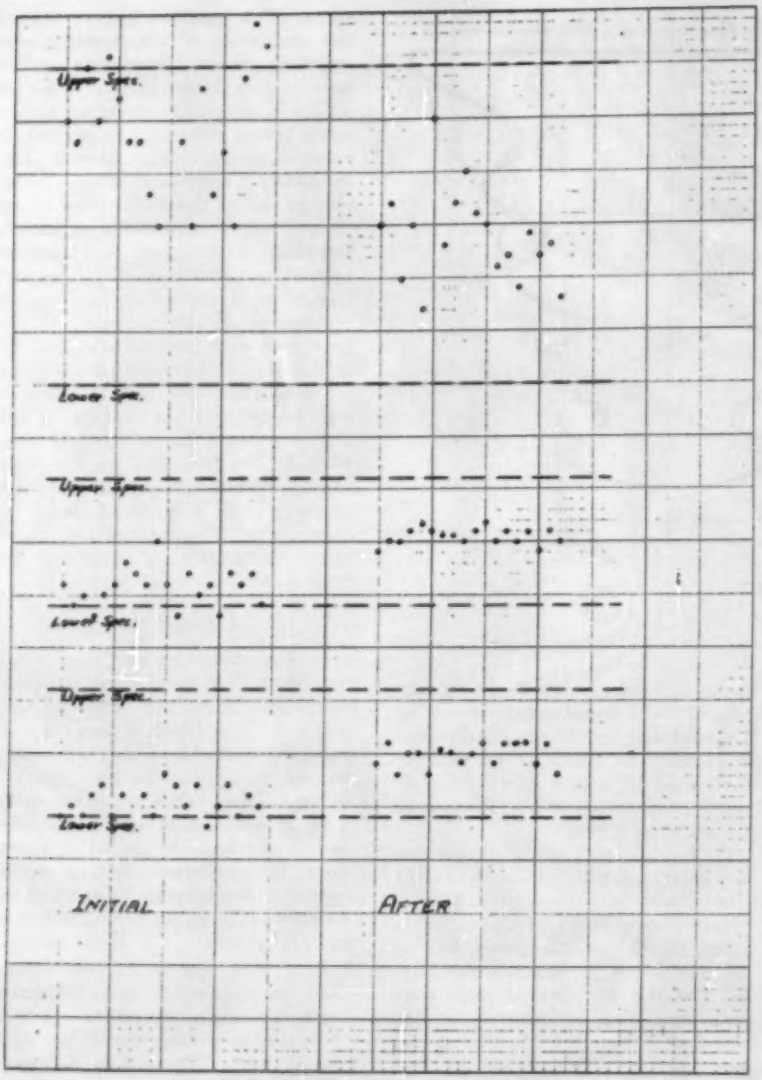


Figure 9—X Chart of Contour Grinding Operation of Turbine Bucket "Dovetail"

relax his tolerance requirements. After seeing the factual estimate of process spread the engineer re-evaluated the application and in this case he found that the 0.0004 inch tolerance would be adequate. He had overspecified on the drawing and consequently the part-cost due to scrap and time lost would have been an unnecessary loss.

A simple median chart (Fig. 10) made by the inspector provided the necessary guides to the operator and he was able to produce at a very low defect level.

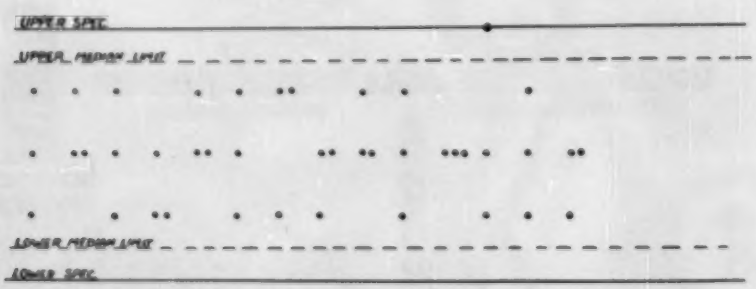


Figure 10—Median Chart of Special OD Grind

Example #5

For some of the buckets that are manufactured, precision forgings are obtained from a vendor. The airfoil section of this forging is complete when it is received except for leading and trailing edge flash. The shank and dovetail sections however, must be ground to size. This grinding must be done in proper relationship to the airfoil section.

The grinding fixture that was made for this job located and supported the bucket with one support located about two-thirds of the way out on the airfoil section and a second support located in the pocket portion of the shank. (See Fig. 11). This pocket support was intended also as support for the grinding pressure. It was found that too much variation in the relationship of the airfoil to the ground shank was being experienced. This caused too many defects. This variation was traced to the relationship that existed on the forgings as they were received.

The time factor made it impractical to redesign the fixture completely or change the manufacture of the incoming parts. However, the existing fixture could be modified to allow shims to be placed under the support for the pocket end. A set up was made to measure the incoming parts and classify them into three groups by the relationship of an estimated airfoil centerline to the pocket location section. To make this measurement a Multiprobe Probograph was used. The set up was designed in such a way that the measurements were plotted on the graph in their correct geometric relationship. A straight line could then be drawn approximating the airfoil centerline. Then by using a marked plastic overlay, classification and grouping of the parts by dimension could be made without actually reading a dimension. This made the inspection and classification simple, accurate, and fast. In manufacture, the groups were machined with suitable shims in the holding fixture to compensate for the variation as measured. Only three classifications were used but by so doing the operator was able to eliminate the defects from this source.

Example #6

Nicks, pits, and scratches are mechanical defects that are caused by careless handling, dirty fixtures,

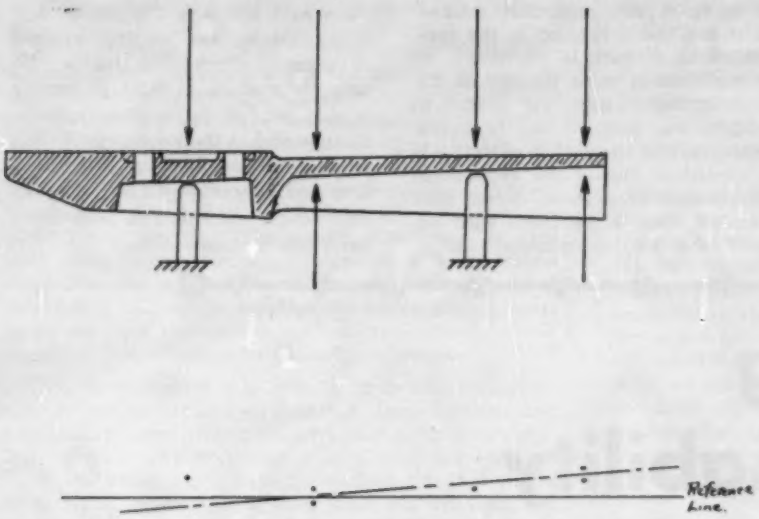


Figure 11—Fixture Support Points for Grinding Shank and Dovetail Sections

sharp edges on holding devices, etc. They are usually detected by visual inspection. Our specification limits on these defects are quite tight since a very small nick in a highly stressed area can cause a complete bucket failure during the factory engine testing prior to shipment. Needless to say this could be catastrophic to the engine. We are therefore very careful about these items in our inspection. Although only a small portion of the bucket is highly stressed and careful inspection can eliminate these defective parts, we find it most desirable to control the processing and handling so that all defects of this type, regardless of position on the bucket, are virtually eliminated.

Recently a campaign to reduce the incidence of this type of defect was inaugurated. A survey of the processing handling operations quickly showed up many sources of trouble. These were eliminated. A repair and clean up operation was established. An educational program was started. The defects due to this cause took a decided drop. However, as soon as the pressure was relaxed, the rate started to climb again until it reached the previous value. Then the program was reinstated and a surveillance inspection on a weekly basis was added. The result has been most gratifying. The scrap rate for the second quarter of 1956 for these causes alone has been reduced by 91 percent over the first quarter. (See Fig. 12). This saving on an annual basis amounts to approxi-

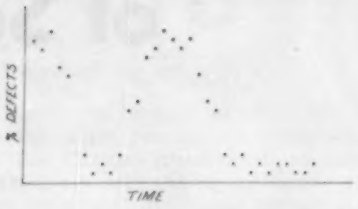
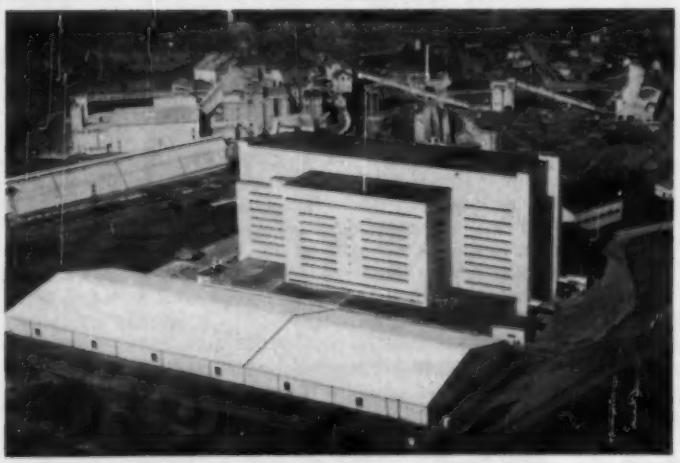


Figure 12—Experience with Nicks, Pits, and Scratch Defects

Quality Control Begins with Research and Development



Through the statistical approach to quality control and progressive development, Johns-Manville has zealously maintained its reputation for quality.

J-M Asbestos Mill World's Largest

As evidence of this research and development Johns-Manville announced late in 1954 the dedication of what would be the world's largest asbestos mill. In fact, this mill when only half completed was the largest in the world. It is now completed and in full operation.

Illustrated here is the mill building located at the J-M Jeffrey Mine at Asbestos, Canada.

Through rigid quality control and the most modern equipment for the milling of high quality asbestos fibres, Johns-Manville is meeting the increasing demands for the higher grades constantly required for new product developments for both home and industry.

Providing a production capacity of 625,000 tons annually, this recently completed asbestos mill provides twenty-two and one half acres of floor area, is 12 stories high. Additional capacity will be added in the near future.

JOHNS-MANVILLE JM PRODUCTS

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mately $600,000.00. In addition to this tidy reduction in cost, higher bucket quality is assured because of the defect prevention program.

Summary

In the execution of the corrective action for quality problems a variety of techniques are used. Sometimes it may be the operation of the process to bring it into statistical control, or it may be a change in the specifications, if such is warranted, or a modification or a change in the process itself may be made to achieve our goal. It can be noted, however, that the goal or objective is a consistent one of the *economical* elimination of defects—*defect prevention*. This is consistent with our pet definition of quality control. "Quality Control is the use of any device, technique, system, method or person which will enable the user to produce product of proper quality for full customer acceptance on time and at the lowest cost." This definition is really only an expansion and adaptation of Ben Franklin's adage. Its effect on profits and sales can be tremendous.

Controlling the Reliability of Soldered Connections

HAROLD KELLOGG

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ABSTRACT

Some military equipment now demands a quality level of no more than one loose connection in 100,000. Such a level of perfection can be obtained only through process controls, not through inspection. These controls include periodic measurements on materials and tools, the collection of objective data regarding process operations, and their analysis on control charts. While manual soldering operations are used here as an example, the same techniques are applicable to any other processes or components. There is no doubt that quality control engineering, earnestly applied to the tools, materials, and people of our jobs, is capable of achieving progressively higher standards of reliability.

Most of our electronic equipment assemblies, whether they are radios, television sets, electronic computers, or guided missile systems contain hundreds or thousands of manually soldered connections. The vast majority of these connections are vital to the reliable operation of the equipment. Because of this it is difficult to overestimate the need for achieving and maintaining the highest possible degree of reliability in each connection we solder.

In most of our jobs at the Western Electric Company we now work to a soldering quality level of no more than one loose solder connection per 10,000 connections made. This is an allowable fraction defective of 0.0001. While this may seen unachievably small, the most outstanding thing about it is that it is not small enough. One of our complex weapons system contains over 75,000 soldered connections. Seven or eight loose connections in this system would be intolerable. In the manufacture of components for one project we are working to a quality level of no more than one loose soldered connection per 20,000 connections. This is just half the allowance made for our regular telephone equipment. Even this is incompatible with the reliability demands of military equipment, and we are trying to improve controls to meet a level of no more than one loose connection in 100,000 connections.

We are currently able to meet both our level of 1/10,000 and our level of 1/20,000 through a combination of diligence on the part of our soldering operators and vigilant 100 percent inspection by our inspection organization. This in turn is followed by an independent sampling inspection by an auditing organization which tells us how well we have achieved our goal.

We are, however, approaching the point of no return when we make demands of this nature on 100 percent inspection. One loose connection per 100,000 is an uninspectable quantity. If, for example, our soldering operations were controlled to the point where they produced two loose connections per 100,000, it would be futile to expect that 100 percent inspection could detect one of the two bad connections. If we are to attain such a level of perfection, it must be through improved process controls rather than through increased inspection.

This is not a new concept. It is the often repeated philosophy of quality control. We must learn to build quality into our products because we can't inspect it into them.

How then do we do this?

Someone has quipped that the electronic industry is at an awkward age—too old to build door bells and too young to build reliable complex equipments.

The answer to this lies in the kit of tools commonly employed by the quality control engineer.

Process Control Replaces 100 Percent Inspection

Many years ago Western Electric quality control engineers developed controls for the process of welding contacts to relay springs. These controls successfully replaced 100 percent inspection and assured the attainment of no more than one insecure weld per 10,000. This level has since been substantially improved. The need for reliability in each weld was so great that a process average fraction defective of 0.0001 (one loose weld per 10,000) was essential. The specification required that each weld be capable of withstanding a seven pound shear test. One hundred percent inspection was tried but was found inadequate because the seven pound shear test was semi-destructive and many contacts which passed it subsequently failed early in service.

The approach that was then taken is standard practice in quality control engineering. Investigations and experiments were conducted with such factors as welding current, surface contamination, mechanical pressure, etc. which were thought to affect the strength of welds. The seven pound shear test was discontinued and in its place small samples of welds were tested to destruction for ultimate shear strength. Control chart analysis of the results of these tests was used to determine the significance of the effect of current, contamination, pressure, etc. on the ultimate shear strength of welds. Through this analysis and engineering of the basic factors affecting weld strength, the average weld strength was raised to a level well beyond the minimum requirement of seven pounds. At the same time the operation of the welding machines was stabilized at this high level. Control chart analysis of the results of periodic sampling was used to assure that controlled operation at this level was maintained. The level at which control was established was sufficiently above the minimum requirement of seven pounds so that the mathematics of the sampling plan makes virtually certain that no more than one in 10,000 welds would shear at seven pounds or less.

The basic methods used to achieve this control are equally applicable to any process, including manual soldering operations. *They involve the refinement of processes through experimentation, the collection of objective data or facts regarding current process operations, and the unyielding pursuit and control of the basic causes affecting the process capability.*

The Process Capability Study

If our equipment is plagued by bad solder connections, there is a reason for it. Behind each loose connection are causes which produced it. It is this system of causes which must be subjected to analysis and control. We want to find out what our process is now doing and why it is doing it. If we're not satisfied with what we find, we want to change the cause system to secure the results we want. The quality control engineer's technical term for this type of applied research is "Process Capability Study." In it the three steps of hypothesis, experiment, and test of hypothesis are transferred from the laboratory to the shop floor and are used for the scientific analysis of complex cause and effect relationships. This is done through exploitation of one of the most basic laws of nature.

We are all familiar with the law which governs voltage-current relationships in an electrical circuit. We call it Ohm's Law. From the laws of gravitation we know that a falling body accelerates at a rate of 32 feet per second per second. This rate of acceleration, like the voltage-current relationship, is dependable because it is governed by a law of nature. The process capability study is dependable because it is based on an equally dependable natural law. This is the Law of Large Numbers.*

Statistical Control—The Key to Reliability Problems

Working with the Law of Large Numbers, quality control engineers have been able to make process refinements which result in almost unbelievably small fractions defective. The Law of Large Numbers has provided them with the key to research, analysis, and control required for the solution of reliability problems because it provides the only known method for precise control of the causes which affect results. This is exactly what we are interested in when we are concerned with reliability. *It may be that as yet we have no method for quantitative measurement of the reliability of such things as a soldered connection but it does not follow that reliability cannot be controlled.* The path for control of reliability lies through control of the causes or variables which affect it.

Let me explain how the Law of Large Numbers deals with this.

Everything Varies

In the first place, the Law of Large Numbers involves the fact that everything varies, that no two things are ever exactly alike. The FBI has popularized the fact that no two finger prints are ever exactly the same. Of the millions studied, there are identifiable differences among them all. Meteorologists tell us that no two snow flakes are the same. Each is a six sided crystaline structure but of the billions that have fallen, each has its own identifying characteristics. The leaves on a maple tree are quickly distinguished from those of an oak but may appear to be identical to each other. However, if we examine leaves picked from the same branch of a maple tree, we will note that each differs from its fellows. They differ in length, in width, in thickness, in shading, and in veining. If we measured we would find differences in moisture content, in chlorophyll content, in acidity.

This same phenomenon is true of product which results from all of our manufacturing processes. Due to the inflexible power of what we have termed the Law of Large Numbers it is impossible to make two things that are exactly alike.

This means that each soldered connection is unique. If examined it is recognizably different from the hundreds of thousands of other connections we make.

Individual Things Are Unpredictable

A second fact in connection with the Law of Large Numbers is that individual things are unpredictable. When we flip a coin we can't reliably predict whether heads or tails will turn up. Even the most learned finger print expert is unable to describe the identifying characteristics of the index finger of the next stranger he meets. In spite of our past knowledge or past measurements, who could venture to predict the exact temperature of a soldering iron tip at any given moment; or the exact weight of solder used by our best operator in making her next connection; the degree of oxidation

*The term "law of large numbers" is used here in the same sense as it is used by Dr. Shewhart in his book, *Economic Control of Quality of Manufactured Product*,—D. Van Nostrand Co. That is, it is based on the "objective probabilities" of quality control theory rather than the more limited mathematical probabilities of the central limit theorem. See pages 122-125; also pages 135, 144, 437, 474, etc.

on the terminal, or the percent of area between wire and terminal that will be fused? Nature's Law of Large Numbers precludes exactness in predictions of this type. It is for this reason that we may make serious mistakes in basing important production decisions on first-part inspection. By the same token, soldering operators are not ready for the assembly line just because they have made a few good soldered connections.

Group of Things Are Predictable

The third part of the Law of Large Numbers is more reassuring. It tells us that groups of things form patterns with definite and permanent characteristics. If, for example, we pour a cupful of sugar out on the table, we have no way of predicting where any individual grain will fall, but we can predict the pattern or shape of the mound that will be formed by the group. We could pour the sugar over again and again, yet each time the group would adhere to the same predictable pattern.

If I were to write a series of "a's" on the blackboard you would note that they were all recognizably different from each other. This is because everything varies. As a group, however, they would follow a pattern which is readily identified as the pattern of my handwriting. The 'a's" I make are obviously different from the "a's" you might write. My handwriting follows a definite and permanent pattern because it results from what we call a constant system of causes. Your handwriting follows another pattern because it results from another cause system. As long as my writing results from a natural system of causes and is not disturbed by unnatural causes, it will continue to follow the same predictable pattern. If I try to write with my left hand the cause system has changed, and so will the pattern of my writing. The conductivity, the corrosion resistance, and the tensile strength of any operator's soldered connections will each follow its own predictable pattern as long as its cause system is controlled. If the amount of oxidation on the terminals to which we connect increases significantly, the patterns for conductivity, corrosion resistance, and tensile strength will also change.

Reliability—An Effect Which Comes by Cause

Unfortunately we have no good production test for all of the important characteristics of a soldered connection. But again, that does not mean their quality or reliability can't be controlled. We do have a test for the thickness of plating, and we have many other tests through which we can control the solderability of the plating we apply to the terminals we solder. Said another way, a large portion of the cause system behind the reliability of soldered connections has to do with the surfaces to which we solder and these causes can be controlled. Using the process capability study, the process control chart, and other of the quality control engineer's sensitive methods for detecting significant differences in measurements or changes in patterns, the plating engineer can control the plating process as precisely as necessary to prevent the reliability of soldered connections from being impaired by poorly plated teminals. But the plating engineer cannot do this if he only *thinks* he has control of his plating process. He can do it only through *shop use* of control techniques which assure him that the plating operation is being affected only by natural, normal causes. The controls must include periodic measurements which, when analyzed on a control chart, will reveal the presence of extraneous or unnatural causes such as excessive fluctuations in plating current, time in tank, solution strength, method of racking, etc.

Once we have established the plating methods that give the results we want, it is relatively easy and inexpensive to measure periodic samples of plated parts, plot the measurements on a control chart, and thus keep track of the causes which affect the plating. These measurements will vary because everything does, but as long as the process is controlled, this variation will follow a normal pattern which is defined by the control chart. If anything extraneous to the system of causes behind this normal pattern interferes with the quality of our plated parts it will show up as instability on the control chart and these parts can be replated, scrapped, or otherwise disposed of. In terms of reliability, the important thing is that they can be kept from being unwittingly furnished to our assembly line as a potential source of loose soldered connections. If, through the engineering of a capability study we are able to establish a state of satisfactory control with respect to the solderability of plated terminals, then these terminals are reliable.

This same type of engineering can be applied to other elements of our soldering operations. Quality control methods provide all the means required to obtain and maintain the necessary uniformity or reliability in the solder or fluxes we use. But again, if we want assurance that the amalgamation or fusion in 100,000 soldered joints is reliably secure, we have to know that the characteristics of our solder and flux are *controlled*. We can't just *think* they are.

We have also learned from experience that the pattern of variation in the cause systems affecting industrial processes is subtly complex and is extremely subject to change with respect to time. This is the reason that continual control chart analysis of important variables is essential to reliability.

Reliability = Control
Control = Reliability

Perhaps at this point we should consider the meaning of the word "control." In the sense used here "control" is a very technical term embodying the philosophy and the mathematics of the Law of Large Numbers. It recognizes that everything varies and that individual variations are unpredictable. At the same time, however, it defines predictability and reliability in that it describes the only constant we know of—the pattern of variation of a natural system of causes. *By definition, if a process is controlled, its performance is predictable and therefore reliable. If it is not controlled, it is not predictable, and therefore it is not reliable.*

In manual soldering operations another basic factor which must be controlled is the soldering iron. In our shops many studies have been made to determine the proper iron for different jobs, the proper method for maintaining the iron, and the interval through which the iron will dependably generate and transfer heat at a satisfactory rate. In one shop, for example, where small copper-tipped irons are used, the tip of each iron is checked twice daily and replaced with a new tip at the end of each day. Before the new tip is inserted, the threads of the iron are retapped to remove any carbonized material which might prevent the tip from seating properly and interfere with its conductivity. After the tip is replaced, the iron is checked to determine that the amount of heat furnished to the tip falls within the normal pattern for that type of iron. The reason for retapping the threads daily is that it has been found

that accumulation of carbonized material can have a significant effect on tip temperature. It is, in other words, an unnatural cause, foreign to the normal operation of the iron, which had to be found and eliminated.

In another of our shops an engineer is currently making a capability study of a new type of iron. One of the main things we want to know about this iron is how well the tip temperature is controlled under ordinary operating conditions. If it is controlled it is reliable and we can make valid predictions about the way it will behave for our soldering operators. If it is not controlled, any reliance we place on it is incompatible with the level of soldering accuracy we are asking for.

All Measurable Differences Are Subject to Control

Capability studies and statistical control methods are also applicable to the operators who do the soldering. In the case of an operator, an important portion of the cause system affecting her reliability is peculiar to her as an individual in the same sense that the "a's" I write on the blackboard are distinguishable from the "a's" you write because we as indivduals are separate cause systems. It is, however, just this difference between operators that provides us with the key we need for precise control of the performance of each. *Through experience in working with the Law of Large Numbers, quality control engineers have learned that wherever there is a measurable difference between apparently similar things, they are subject to control and the causes which affect them can be studied.*

We are interested in the soldering operator's ability to perform a repetitive task thousands of times with sufficient accuracy to assure that each connection is mechanically secured to the proper terminal and that the heat, solder, cooling cycle is sufficiently controlled so that the variations which exist between the ensuing soldered joints will not be great enough to affect the security or reliability of the connection. Because as yet we have no economical production test for making a quantitative measurement of the reliability of each joint, we have to control the reliability of the connections through controlling the reliability of the operator's performance. To do this we need some method of measuring the difference between operators. In the case of contact welding we measured the difference in welding machine operation with respect to time by performing destructive tests on samples of welds. In the case of wrapped soldered connections, however, we have no satisfactorily indicative destructive test which can be used on a production basis. Therefore we look beyond the soldered joint itself for a measurable quantity which is indicative of the difference between operators.

Point Evaluation as a Substitute for Direct Measurement

At Western Electric Company we have for many years been measuring and controlling the performance of soldering operators through a point evaluation of the total connecting and soldering task they perform. Before our operators are allowed to participate in production soldering they are given thorough off-the-job training and experience. This training extends over a period of several weeks and includes a discussion of the theory of soldering as well as patient teaching of proper connecting and soldering methods. Each operator is given the opportunity to practice and develop her ability under the guidance of the instructor. Along with this she is taught to recognize all of the attributes of a good soldered connection and all of the items which we feel detract from a good soldered joint. This latter list of what we consider undesirable characteristics has been deliberately expanded to include a number of relatively minor defects. Included in it are:

- Connection not soldered
- Connection insecurely soldered
- Wire connected to wrong terminal
- Cold solder
- Disturbed solder
- Wire nicked
- Broken wire strands
- Mechanical wrap improperly made
- Excessive solder
- Insufficient solder
- Excess resin on terminal
- Insufficient clearance due to soldering
- Wire end not clipped
- Solder splatters
- Wire clipping in unit
- Insulation back too far
- Insulation in solder
- Insulation burned
- Insulation frayed

Although not all of these defects necessarily affect the reliability of the connection, prevention of their occurrence imposes high workmanship standards on the operator. It is this list of attributes which is used to appraise the operator's work and score her ability to consistently perform her task in the specified manner. Through this total appraisal of the operator's performance, we are able to measure her repetitive accuracy with much greater precision than we could if we merely appraised her work for the presence or absence of a functionally acceptable soldered connection. This point evaluation of each operator's work gives us the measure we need of the difference between operators. The ratings for each operator, if plotted on a control chart, tell us the level of accuracy of each operator and the limits within which this accuracy varies. If the operator's performance is affected by a natural, normal system of causes, the pattern of variation in the occurrence of defects in successive samples of her work, as reflected on her control chart, will fluctuate in a recognizably normal manner. If on the other hand something upsets her ability to consistently maintain her accuracy, this will be reflected on her control chart as an indication of instability. More frequently than not she, herself, will know what it is that is interfering and, having realized it is influencing her performance, can adjust for it. The work she performed during the interval covered by the appraisal can be rechecked, resoldered, or otherwise disposed of. At the same time, since we are able to distinguish between the accuracy of operators, we are also able to study the performance of the better operators in an effort to determine what they do that makes them better. If discernible, this can then be incorporated in the performance of others.

This method of controlling the operator's influence on the reliability of soldered connections is based on the theory that when the materials we solder to and the solder and tools we use are satisfactorily controlled and the operator consistently follows instructions, the occurrence of a functionally unsatisfactory connection will have an extremely small probability. There is no doubt that quality control engineering, earnestly applied to the tools, material, and people of our soldering jobs, is capable of achieving progressively higher standards of soldering reliability.

It may be of interest to note one final bit of evidence on the reliability of soldered connections at Western Electric which is provided by the environmental testing of completed equipments. During the past several years many of our electronic systems containing in the aggregate hundreds of thousands of connections have been subjected to rigorous temperature and humidity cycling, shock, and vibration. As yet this environmental testing has revealed no equipment failures due to an inadequate soldered connection.

Practical Chemical Process Control*

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Abstract

The practical consideration of the how, why, and wherefore of chemical process control principles discussed here stresses the need for careful matching of statistical quality control methods with chemical requirements. The steps for attaining process control, from appreciation of its need through quality audit, are reviewed in detail. Examples illustrate some of the problems encountered in practical applications.

Introduction

Adequate management of any organization includes control in the form of checks and balances to assure that each division is meeting its responsibilities and not overstepping its authority. For chemical manufacture, this guiding or limiting phase may be delegated to production supervision, to the technical staff, or to the control laboratory. The success of the designated group may well determine plant capacity, product quality, process economics, labor costs, and reaction yields. For this particular assignment, technical competence is not sufficient. Knowing where to look must be tied to knowing how often to look. Even "on-the-spot" analyses and first rate sampling do not produce their best results unless some action values are prescribed to distinguish between natural process fluctuations and undesirable reaction changes. The philosophy of quality control with its tenets of "value for cost expended", "prevention, not correction", "anticipation versus afterthought", and "fact versus opinion" has much to offer in the fast growing field of process control.

What Is Process Control?

Process control is known by many names—intra-plant quality control, chemical control, chemical inspection, operational control, and others. Regardless of the name applied or the field of endeavor, the methods have certain characteristics in common. Just as the mechanical industry in its inspection requires and provides for:

a. interpretation of the specification
b. selection of the product to be measured
c. measurement of the product
d. comparison of the interpretation and the measurement
e. judgment as to conformance
f. disposition or action
g. record keeping (16)

so must the chemical industry judge its ability to meet customer requirements whether they be those of the adjacent process step, another company, or the public.

Process control concerns itself with guidance during manufacture with the aim of anticipating process changes in such a way that they may be corrected or modified before they adversely influence reactants. Dealing with the material undergoing change, such control centers about operational procedure, equipment maintenance, instrument calibration, and their various effects on measures of reactant quality characteristics. For control, it is the process that is of interest rather than the end product, whether the method of processing be batch, semi-continuous, or continuous.

Why Have Process Control?

It is the nature of chemical manufacturing itself that demands process control. Large volumes of material, high vessel holdup, long reaction periods, significant effect of operating variables (time, temperature, flowrates), low conversion, and high recycle ratios all suggest the need for constant observation if full plant capacity is to be obtained. Since most plants are designed to handle the product stream only once, rework, blending, recovery and additional upgrading steps prove costly. It has become more economical to "make the product right" than to sort it. In some chemical processing, quality requirements have not yet been developed to the point where it has been necessary to exert such control to make the product acceptable. As such, process control may not be justified in terms of higher quality. However, greater yield, lower operation cost, and lower indirect expense may accrue from its use. For such a case, the added advantage of being able to control the process more closely, should the need arise, puts the manufacturer in a desirable position for entrance into a higher quality market.

How Is Process Control Attained?

Process control comes only after an appreciation of its need. Furthermore, this understanding must permeate the entire organization. Little good is accomplished if only the manager is concerned with quality. The operator must also demonstrate his awareness and interest by attention to the many details of daily operation.

Selecting the points in the overall process for control constitutes the next step. The choice is influenced by the relative importance of the various stages, ease in handling the product stream or samples from it, temperature and pressure conditions, degree of mixing present, ability to make meaningful control measurements, stability of samples when removed from the reaction atmosphere, and the hazardous nature of the material. In part, the choice is also influenced by the available chemical and physical test methods for evaluating conformance at the points under consideration. This includes usable instrumentation for both indication, measurement, and automatic control. Important characteristics of such detection and sensing methods are: (a) low lag, (b) fast response, (c) ease of cali-

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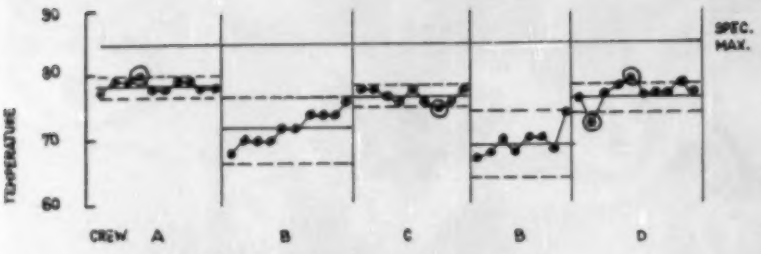

Figure 1—Comparison of Operating Crews

bration, (d) adequate accuracy, precision, and reproducibility in the range needed. Simultaneously with check point and test method selection, performance standards must be derived for the particular points involved.

After the mechanics of process control detection and evaluation are established, corrective procedures must be incorporated in the operating manual to assist the operators. Supervision "follow-up" aids quality assurance and further substantiates the importance of adequate control in the operator's mind. Independent audits by the quality assurance group periodically submits the original plan to review and improvement.

From this discussion it is apparent that establishing process control depends on the coordination and cooperation of many groups. Each contributes in its field of activity, thus assuring the fullest use of specialists from production, supervision, engineering, research, and quality control.

The Place of Statistical Methods in Process Control

Process control has been achieved for years without the benefit of modern statistical procedures. However, increased complexity of reaction, and greater understanding of the underlying chemical kinetics coupled with the need for greater economic yields have necessitated additional methods for control. Greater precision and accuracy of analytical methods and the influence of small amounts of certain impurities have fostered the move toward higher quality.

Statistical methods are not a panacea for processing troubles. However, they are useful in determining process capabilities, finding out whether control is possible at the levels and with the variation allowable, and indicating the influence of sampling variation and the effect of test methods errors on decisions.

By observing individual samples or batches the natural process tolerance may be determined. In such a process capability study, trends, cycles, and shifts in average or dispersion may be correlated with corresponding changes in operation variables, raw materials, or personnel. It is frequently necessary to make such an investigation before augmenting present process controls. Control limits may be computed[7] for the results of the study and used for process review. Figure 1 depicts typical variation in product temperature associated with different operating crews.

The principle of "statistical control" is a valuable adjunct to chemical control methods. As such, it tells when a process is varying more than expected. It also emphasizes the need for action based on preselected probabilities. For chemical work, "individuals" control charts, moving range control charts, and average charts with 2-sigma limits are suggested as means of checking the process during a start-up[3]. In addition to telling when a process has reached control, statistical control charts are used to maintain control. Run theory (runs above and below the central line, runs up and down, and moving range charts) increases the power of the individual and average charts in detecting small changes of importance[2]. The advantage here, is that runs may be computed as easily as sums by operators.

Statistical methods play a vital role in evaluating variation in sampling. The problem of physical sampling in the chemical field is worthy of a paper of its own (*vide*[23]). Sampling difficulties are appropriately investigated in choosing the points for process control. For the cases where control rests completely on samples to be analyzed, detailed investigations are recommended. During this study, tests are made to determine sample representativeness, randomness, and variability. Without the first characteristic, the sample has no meaning. Without the second, statistical methods lose their value. With too much of the third, confidence is lost in their results. For this work variance analysis, significance tests, and regression analysis may be needed[5,9,19,26]. Assumptions of homogeneity and adequate mixing in blending or intermediate product storage tanks need verification.

While not a direct part of process control, test method variation and bias influence the size of sample to be taken, and the manner in which the sample is to be handled during analysis. Statistical evaluation of test variation produces information

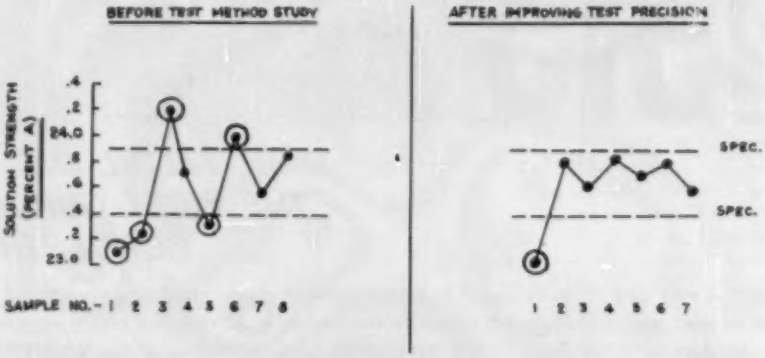

Figure 2—Test Reliability Influences Production Decisions

Sample No.	Action	Sample No.	Action
1	Continue reaction	1	Continue reaction
2	Continue reaction	2	Meets specs.
3	Dilute with water	3 (check)	O.K.
4	Meets specs.	4 (check)	O.K.
5 (check)	Add more A	5 (check)	O.K.
6	Dilute with water	6 (check)	O.K.
7	Meets specs.	7 (check)	O.K.
8 (check)	O.K.		

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as to accuracy, precision, need for blank determinations, and answers as to whether duplicates, replicates or composites may be used to satisfy a given budget and uncertainty range[6,19,20,22,30,34]. The number of analyses necessary to approve a batch may be substantially reduced, as shown in Fig. 2, by a test method study.

Again, as a by-product of such work, a check sample program would be established to verify accuracy and precision of control samples on an assurance basis[32]. Control charts on check samples may be used to report data to production supervision. An alternative procedure more desirable from a psychological viewpoint, is to plot check sample results on the control charts in the operating areas.

Another indirect phase of process control that precedes the mechanics of sampling, measuring, and decision is that of assessment to each of the operating variables of its importance in influencing the process step concerned. If done in the pilot plant or laboratory, experimental designs available may be used. (Another advantage of correlation studies in pre-plant scale tests is that of specifying process instrumentation along with process design requirements for vessels, agitation, and piping.) If plant data are used, multiple correlation methods are usually most fruitful. Here again, coordination from various departments is essential to quick, meaningful interpretation. The results of such investigations should establish those variables to be controlled and the range of control important. For a process whose control is difficult or dangerous recently proposed techniques[1,4] may allow optimizing "control" without serious loss of yield. In some cases, other nonstatistical methods would declare the process unfeasible.

Errors in Process Control

All phases of manufacture have lore derived from past experience. Frequently, advances in theory show part of this practical knowledge to be in error. Process control, in spite of recent emphasis, has not been spared its share of misconception.

For a long established process having equally standardized product specifications, a common mistake is to apply acceptance criteria for the finished product to the process at some intermediate point for process control. In some cases, tests made on finished product are interpreted in terms of influence on a given process stage. The danger here is that the product specifications may reflect difficulties the customer has with the product from a use standpoint and in no way correlate with the steps that produced these characteristics. By way of example, product color to the fabricator may mean high or low customer acceptance of his product. To the chemicals manufacturer it may mean poor purification, washing, or leaching. In the explosives industry, the steps that go toward making an explosive chemically stable must be controlled by tests different from those that report this stability present in the finished product. Only in processes where correlation of product characteristic and process variables has been carried out should such procedures be used, and here only when economics dictates.

A second source of trouble in process control work is to assume that samples analyzed in the control or standards laboratory are more precise and more accurate than those run on the production line at control points. It may be argued that the equipment, atmosphere, and training of the laboratory people better equips them to do superior work. This may be so, yet other apparently extraneous factors may invalidate the best laboratory analysis. To illustrate, the points at which the laboratory and control samples are taken may differ. As a result of this, one may be cool, solid flake while the other may be hot, molten liquid. Loss of volatiles may occur. Contamination may occur in transit or storage awaiting analysis. Additional processing may occur between control and laboratory sample. The former may be taken from a well mixed vessel, while the latter may come from several of many packages. In some cases, control samples are taken from the process stream while laboratory samples are taken from a tank, thus being subjected to compositing. From a human relations view, the control sample is of immediate concern to the operator. To the laboratory personnel, it's just another sample to be run from "tank A17". While sufficient argument may be presented in favor of the laboratory, scientific evaluation is preferred to an unjustified assumption. Furthermore, no quality assurance program can complete its audit without such a check on process control and standards laboratory alike. A control chart (shown in Fig. 3) for difference of melting point run by both plant operators and lab technicians on the same batch performs this function at one of Atlas Powder Company's plants.

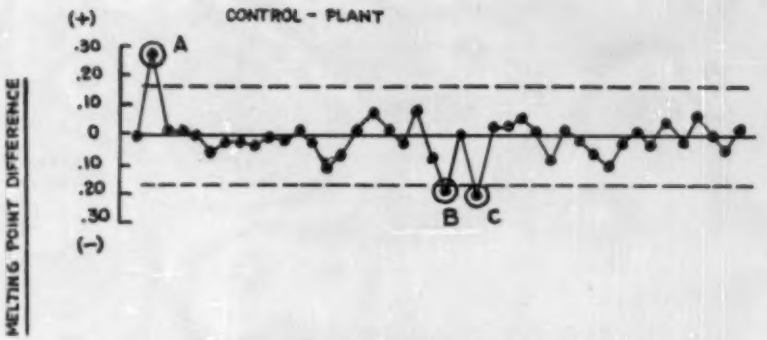

Figure 3—Comparison of Control Laboratory and Plant Tests

Notes: A New Laboratory helper
B Replace plant thermometer, mercury separated
C Check dry product compositing

Occasionally, in a particularly difficult processing step the control laboratory will suffer loss of confidence in the eyes of production supervision. The tendency then is to do as production asks to regain this lost prestige while solving the problem. This leads to a third process control weakness: that of agreeing to take additional samples or to run more analyses when duplicates or replicates on the first sample were too variable, without a statistically sound plan for the evaluation of *all* the data obtained. The effect of this is to bias the results by rejecting without adequate justification. While tests are available for the rejection of dubious results[10] they are generally not followed correctly or are generalized to the point of being misleading[23]. It is preferable in such cases to evaluate immediately test method variability and accuracy so that adequate precision can be obtained for decisions on process improvement[21]. While temporarily expensive, such a procedure permits the laboratory to function properly while pursuing more precise meth-

ods. At the same time, a process capability study at increased sampling rates may serve to point out the difficulty and define the feasibility of the specification-process relationship in light of test method variation[14].

Advocates of process control suggest talking to production personnel for first hand suggestions on where to start process control and how it can best function. Furthermore, they suggest for a successful program that production personnel implement the controls with charts in operating areas. In spite of the best training sessions and production familiarity with quality control methods this situation has all the conditions necessary for another process control error. The problem that arises has to do with interpretation of what is necessary and sufficient for control. Although production supervision may understand the criteria discussed at the onset, frequently production operators hold an entirely different version of what is needed, and the meaning of this. This may lead to either "over control" or "under control" of the selected variable, and perhaps, even lead to regulation of an unimportant variable.

To illustrate, production operators were running two simultaneous freezing point determinations on molten product being dried. If the average was above a given value and the difference was in control, the next operation was immediately started. If the average was less than the action value, drying was continued for the prescribed time until two more replicates were run and the results known. At this point, the product was classified: "acceptable", "doubtful" (subject to control laboratory verification) or "reject". In any event, the next operation was commenced and the graded product shipped, held in storage awaiting laboratory results, or held for rework, respectively. Differences in the average freezing point obtained by process control and the control laboratory suggested that the replicate values obtained by the process group be averaged and recorded for further analysis. Analysis of the data showed exceptionally good agreement between replicates; in fact, statistically significant lower variation than expected. In addition, the process control values averaged higher than the laboratory (in the direction of better quality) and had lower variation. At this point, discussion with operating personnel disclosed several misconceptions:

(a) One production line never had complied because their foremen didn't think it was important;

(b) Because different apparatus were used for each replicate, thus requiring a different calibration correction, a second production line was found to be computing an arbitrary second value and recording it as a bona fide observation;

(c) One operator on a third line had observed that the laboratory had run 0.1 degree above the process control values. He had also observed that coincident with this his operation had performed a sizable amount of rework before the lab results were received. Whenever he obtained values approximately 0.1 degree too low he "raised" them to the acceptable range.

(d) A fourth production line admitted to recording the actual value only as long as it was within the range that the laboratory checked; above that they "guessed" what it might be.

Correction of this error was obtained after adequate explanation of the value of such readings to the operators themselves, in reducing the amount of rework to be handled. To permit such haphazard process control would be equivalent to modifying the conformance standards for each individual operator.

Occasionally, a situation considered to be ideal gives more trouble than thought possible. At a weighing station, an operator had a complete description of his duties which consisted of placing a fiberboard box containing a liner under a hopper, filling with a given amount of dry, flake material, and then pushing the box down a roller conveyor. He also had an indicating scale marked with warning zones and in-specification zones in different color, a procedure to zero the scale tare, and finally a test weight equal to the amount of material to be weighed out. In spite of this, packaged material was running below weight specifications. An investigation showed:

(a) that the calibration or taring knob was at knee level and by accident was being misaligned every so often;

(b) the operator *assumed* the scale to be checked by the instrument shop once a shift;

(c) the production rate wasn't uniform — several batches would be run through quickly and then none were made while the men had lunch or smoked;

(d) boxes check-weighed by another operator further down the line were set aside but rarely reported to the errant operator.

No process control was possible at this station until the operator had been convinced that it was his responsibility to weigh each filling correctly. Furthermore, he had to be sold on the idea that it was to his advantage to do the job correctly, and finally that his part in the scheme of things was most important. Then, to convince the operator that quality control was sincere in its efforts, a plan was outlined providing process control on a roving inspection basis. The plan would provide checks against which the operator could judge his own performance. The fundamental error in process control here was that the operation was so simple that it did not appear to need control. As a result, control that could have been built-in to the process was lost.

Recent Advances in Process Control

From the criteria proposed for adequate process control it is apparent that improvements are to come from advances in supervisory, chemical, and statistical fields. Refined instrumentation methods, better understanding of chemical problems, clearer evaluation of existing processes, and greater emphasis on end product quality contribute to superior process control.

With a goal of closing the gap between sampling and measurement, chemical development has produced more useful "spot tests" applicable to production line control. Research is being done on better endpoint determinations for automatic equipment. High frequency radiation and electronic field methods are advancing the use of "probes" in measuring process streams rather than sampling. Radioactive tracer methods may not be too far in the future for flow measurements and the like. Many chemical laboratories are reporting the certainty of their analytical results in probability confidence limits to guide other researchers and production supervision in their use.

Statistical assistance in process control has come in the form of short-cut methods, such as ranking procedures[28,31] and the use of the range[15,17,18,29] for cases where sampling and measurement is cheap but computation expensive or awkward.

(Continued on page 54)

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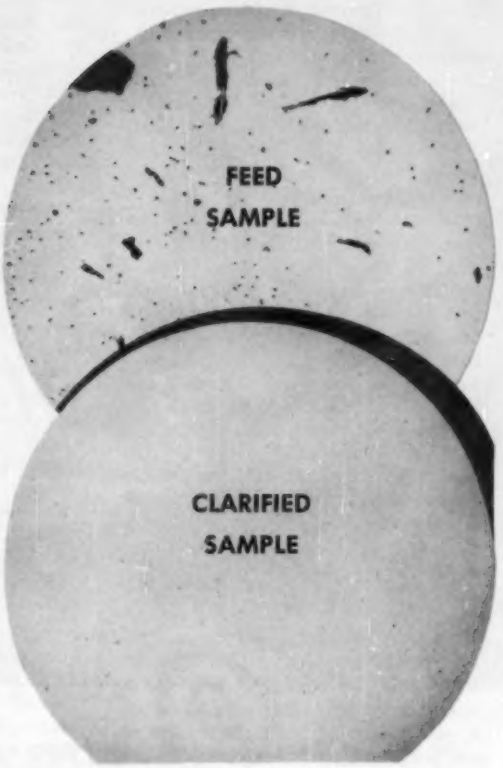

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(Continued from page 51)

Punched card methods now permit more advanced analysis of process control variables[25]. In addition, more plant data are being evaluated as well as taken because such methods are present. Continuous sampling plans[11,12,13] are freeing more control laboratories from product acceptance testing while guaranteeing average outgoing quality limits. Such methods allow more time for process control methods evaluation and better process control necessary for correct operation of these acceptance plans. Control chart acceptance of product also minimizes laboratory analysis and takes acceptance from the product back to the line. Sampling frequency and sample size determination is moving from the art stage to a science with the development of power curves for the various statistical procedures. Greater use of composite samples, with attendant savings, is feasible in light of proposed sampling evaluations published[8,27]. Use of sequential methods for control decisions on a variables basis offers additional savings in time and tests. Sequential t-tests and their range analogue show the sample evaluation necessary for risks generally selected. In process control work, more quality audits are needed to substantiate the efficiency of plans used and assumptions made.

Instrumentation progress has been directed to automatic control on a continuous basis[24,35]. Mass spectrometers, infra-red and ultra violet analyzers, pH, conductivity, moisture content, refractive index, viscosity, and oxidation-reduction potential controllers are available for continuous stream measurement and control. While application at this time may be limited for economic reasons, more processes are going on stream daily only because of such developments.

A Look to the Future of Process Control

Greater evaluation of process control needs will come from the use of analog and digital computers in simulating processing conditions on a pilot plant scale. Substitution of mathematics for chemical trial runs may not be appealing to the chemical engineer at the start; however, the additional information available will allow him to direct his attention to better design and control research. Complete automatic processing will require the generation of process control techniques and conformance evaluation. Spot checks will still be necessary as a check on instrument calibration. More mechanized means of evaluating processing data will give the process control engineer greater opportunity to plan data collection and interpretation. Higher sampling rates will then be feasible for greater control. At present, lower sampling rates are the goal since analytical costs are high. On a mechanized basis the trend will be toward greater assurance by higher sampling rates with rapid, low cost evaluation terminating in automatic control decisions.

Automatic processing depends on continuous control for operation. The feedback nature of such control systems contains a lag in response. Statistical evaluation of control data can be used to anticipate more closely changes in average level and dispersion until processes are put on an exact basis and measurement errors minimized.

Summary

Process control should be the coordinating link in manufacturing that brings to fruition the efforts of the design engineers, development chemists, and production supervision. Anticipatory in effect, process control aims not only for high quality, but also for low cost, high yield, high conversion, and full plant capacity utilization. It accomplishes these goals by *selling* the operators the advantage of using the graphical methods and chemical tests available for frequent checks on the state of the process. For practical application, process capability must be known, methods of correction be available, and action limits prescribed to separate process fluctuation from technically important reaction changes. Since production personnel can not be expected to make correct decisions from faulty information, process control must necessarily include periodic checks on the accuracy, precision, and reproducibility of the chemical test methods used.

Quality-mindedness is the clue to good practical process control. While outstanding chemical tests and statistical methods will carry a control program, only the combination of these with convinced, informed, interested operators will insure success for a concerned management.

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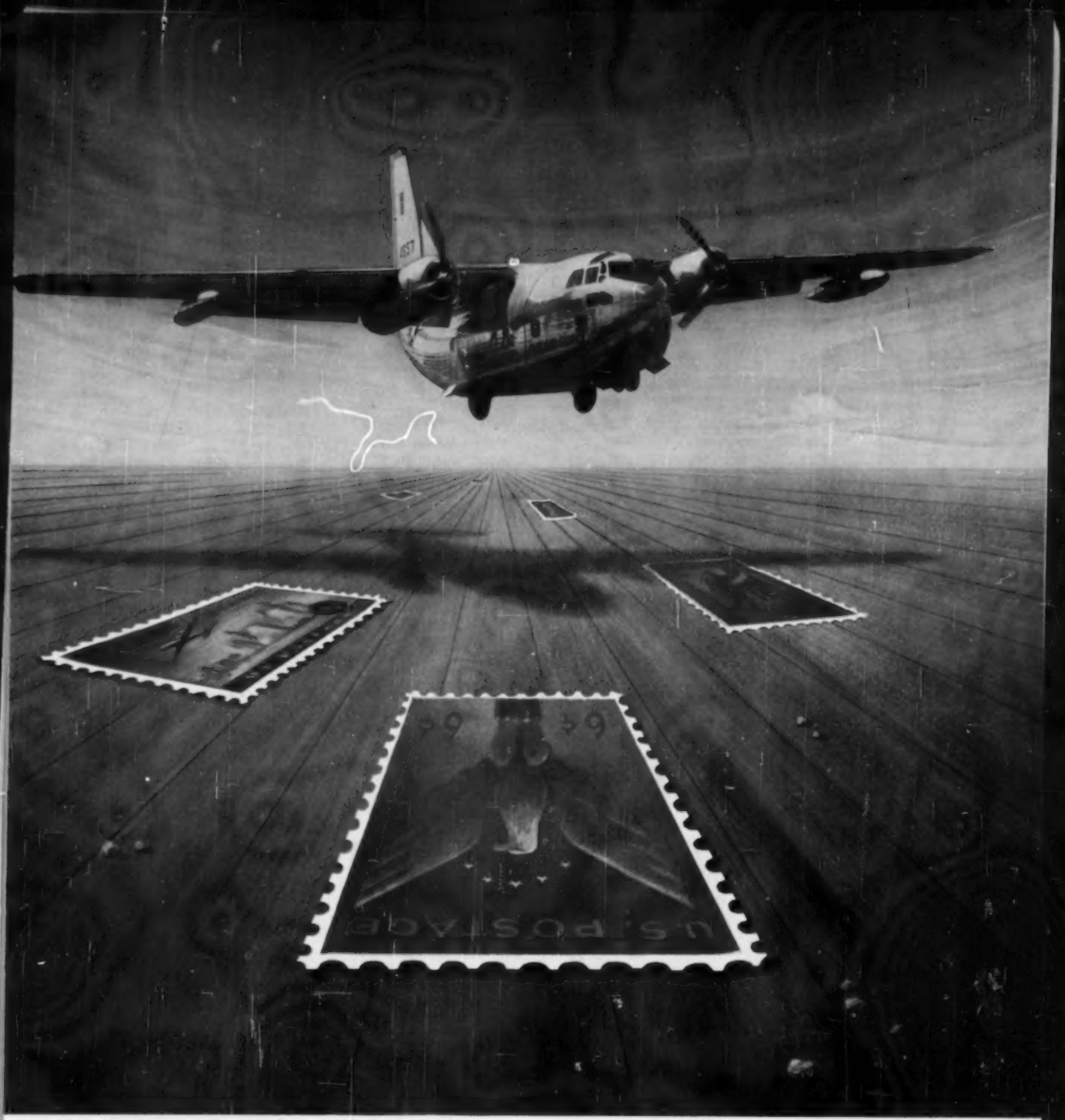

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Binomial and Poisson Confidence Limits

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Routine statistical analysis in engineering and quality control generally involves one or more of the following six fundamental distributions:

1. Normal Distribution
2. Student's t Distribution
3. Fisher's F Distribution
4. Pearson's Chi-Square (χ^2) Distribution
5. Poisson Distribution
6. Binomial Distribution.

Almost all statistical and quality control texts give rather satisfactory tabulations of the first three distributions and many have tabulations of the next two. But very few give a table for the Binomial Distribution and those that do often arrange the tabulation in a form that is inconvenient for routine use. The purpose of this article is to point out that confidence limits for the Binomial Distribution are easily obtained from any table of the Fisher F Distribution. Similarly, confidence limits for the Poisson Distribution are easily obtained from the Chi-square (χ^2) Distribution.

The Binomial Distribution

In order to calculate binomial confidence limits, one needs appropriate conversion factors. Suppose d defectives are observed in a sample of n items and γ confidence limits are to be calculated using a table of the F Distribution when m_1 is the number of degrees of freedom in the numerator and m_2 is the number in the denominator of the F ratio. The necessary conversion factors are:

Confidence Limit	Degrees of Freedom	
Upper	$m_1 = 2(d+1)$	$m_2 = 2(n-d)$
Lower	$m_1 = 2(n-d+1)$	$m_2 = 2d$

γ Limits for the True Value of the Fraction Defective

$$p_U = \frac{(m_1 F_\lambda / m_2)}{1 + (m_1 F_\lambda / m_2)}; \quad \lambda = (1-\gamma)/2$$

$$p_L = \frac{1}{1 + (m_1 F_\lambda / m_2)}; \quad \lambda = (1-\gamma)/2$$

Example 1. Suppose four defectives are observed in a random sample of fourteen items. What are 90% confidence limits for the true fraction defective, p', in the lot from which this random sample was selected? The analysis is as follows:

1. $d = 4$
2. $n = 14$
3. $\gamma = 0.90$
4. Upper Limit:

   $m_1 = 2(d+1) = 10$; $m_2 = 2(n-d) = 20$;

   $\lambda = (1-0.90)/2 = 0.05$

   $F_{5\%}\ (10,20) = 2.35$

   (Taken from any standard table of the "F" Distribution. Note that the level used is $(100\% - 90\%)/2 = 5\%$ since the tabulated F Distribution refers only to one, not both, tails.)

   $$m_1F/m_2 = (10)(2.35)/(20) = 1.18$$

   $$p_U = \frac{(m_1F/m_2)}{1 + (m_1F/m_2)} = \frac{1.18}{1 + 1.18}$$
   $$= 0.542 = 54.2\%$$

   Therefore one is 95% confident that the true fraction defective, p', is at most 54.2%.

5. Lower Limit:

   $m_1 = 2(n-d+1) = 22$; $m_2 = 2d = 8$;

   $\lambda = (1-\gamma)/2 = 0.05$

   $F_{5\%}\ (22,8) = 3.14$

   $m_1F/m_2 = (22)(3.14)/(8) = 8.64$

   $$p_L = \frac{1}{1 + (m_1F/m_2)} = \frac{1}{1 + 8.64} = 0.104 = 10.4\%$$

   Therefore one is 95% confident that the true fraction defective, p', is at least 10.4%.

6. Confidence Limits:

   The relationships,

   $p' \leqq 54.2\%$, (95% confidence),

   $p' \geqq 10.4\%$, (95% confidence),

   imply, with 90% confidence, that the true fraction defective, p', in the lot is within the range.

   $10.4\% \leqq p' \leqq 54.2\%$.

Example 2. Suppose no defectives are found in a random sample of ten items. What is the 99% upper confidence limit for the true fraction defective, p', in the lot from which the sample was selected? The analysis is as follows:

1. $d = 0$
2. $n = 10$
3. $\gamma = 0.99$
4. Upper Limit:

   $m_1 = 2(d+1) = 2$; $m_2 = 2(n-d) = 20$;

   $\lambda = 1 - 0.99 = 0.01$

   $F_{1\%}\ (2,20) = 5.85$

   (Note that the level used is $(100\%-99\%) = 1\%$ since we are here determining only the upper confidence limit, not both the upper and lower.)

   $$m_1F/m_2 = (2)(5.85)/(20) = 0.585$$

   $$p_U = \frac{(m_1F/m_2)}{1 + (m_1F/m_2)} = \frac{0.585}{1.585}$$
   $$= 0.369 = 36.9\%$$

   Therefore one is 99% confident that the true fraction defective, p', is at most 36.9%.

5. Lower Limit:

   When no defectives are observed, the lower confidence limit is always zero, which corresponds to 100% confidence:

   $p_L = 0$

   $p' \geqq 0$ (100% confidence).

6. Confidence Limits:

   The relationships,

   $p' \leqq 36.9\%$ (99% confidence),

   $p' \geqq 0$ (100% confidence),

   imply, with 99% confidence, that the true fraction defective, p', in the lot is within the range

   $0 \leqq p' \leqq 36.9\%$.

Poisson Distribution

Since the Poisson Distribution is the limit of the Binomial Distribution as the sample size becomes large and p' becomes small, with np' fixed, confidence limits for the Poisson can be easily calculated from the χ^2 Distribution (which is the corresponding limit of the F Distribution). Suppose b defects are observed in a random sample of size n. What are γ confidence limits for the true average number of defects, np', expected for a large number of similar samples of the same size, n? The necessary conversion factors are:

Confidence Limit	Degrees of Freedom
Upper	$m_U = 2(b+1)$
Lower	$m_L = 2b$

γ Limits for the true expected number, np'

$$(np)_U = \chi_U^2/2 = \chi_\lambda^2\, m_U/2; \quad \lambda = (1-\gamma)/2$$
$$(np)_L = \chi_L^2/2 = \chi_\lambda^2\, m_L/2; \quad \lambda = (1+\gamma)/2$$

Example 3. Suppose six defects are observed in a random sample of 100 yards of cloth. What are 90% confidence limits for the true average number of defects, c', per yard in the lot from which the sample was taken? The analysis is as follows:

1. $b = 6$
2. $\gamma = 0.90$
3. Upper Limit:

   $m_U = 2(b+1) = 14$; $\lambda = (1-0.90)/2 = 0.05$

   $\chi_{5\%}^2\,(14) = 23.7$

   (Note that the level used is $(100\%-90\%)/2 = 5\%$.)
   $(np)_U = \chi^2/2 = 23.7/2 = 11.9$

   Therefore one is 95% confident that the true expected number of defects, np', is at most 11.9.
4. Lower Limit:

   $m_L = 2b = 12$; $\lambda = (1+0.90)/2 = 0.95$

   $\chi_{95\%}^2\,(12) = 5.23$

   (Note that the level used is $(100\%+90\%)/2 = 95\%$)
   $(np)_L = \chi^2/2 = 5.23/2 = 2.61$

   Therefore one is 95% confident that the true expected number of defects, np', is at least 2.61.
5. Confidence Limits:

   The relationships,

   $np' \leqq 11.9$, (95% confidence),

   $np' \geqq 2.61$, (95% confidence),

   imply, with 90% confidence, that the true expected number of defects, np', *per 100 yards* is within the range.

   $$2.61 \leqq np' \leqq 11.9.$$

   Since this refers to $n = 100$ yards, the true expected defects *per yard*, c', is within the range,

   $$\frac{2.61}{100} \leqq c' \leqq \frac{11.9}{100},$$

   $$0.0261 \leqq c' \leqq 0.119,$$

   with 90% confidence.

Example 4. The laboratory reports that no "specks" were found in a one pint sample of oil. What is the upper 90% confidence limit on the true average number of specks, c', expected per 50 gallon drum? The analysis is as follows:

1. $b = 0$
2. $\gamma = 0.90$
3. Upper Limit:

   $m_U = 2(b+1) = 2$; $\lambda = 1 - 0.90$

   $\chi_{10\%}^2\,(2) = 4.61$

   (Note that the level used is $100\% - 90\% = 10\%$ since we are here determining only the upper limit.)

   $(np)_U = \chi_U^2 = 4.61/2 = 2.31$

   Therefore one is 90% confident that the true expected number of specks, np', is at most 2.31 per pint of this oil from the same source as the laboratory sample.
4. Lower Limit:

   Since no "specks" were found in the sample, the lower confidence limit is zero, which has 100% confidence:

   $(np)_L = 0,$

   $np' \geqq 0.$ (100% confidence)
5. Confidence Limits:

   The relationships,

   $np' \leqq 2.31$, (90% confidence),

   $np' \geqq 0$, (100% confidence),

   imply, with 90% confidence, that the true average expected number of "specks", np', *per pint* is within the range.

   $$0 \leqq np' \leqq 2.31$$

   Since a 50 gallon drum contains $(8)(50) = 400$ pints, the 90% confidence limits for the true average expected number of specks, c', *per drum* are

   $$(400)(0) \leqq c' \leqq (400)(231),$$

   $$0 \leqq c' \leqq 924.$$

A Suggestion

This use of the F and χ^2 distributions to evaluate the Binomial and Poisson distributions is very convenient if we write the conversion formulas in the margins of the F and χ^2 tables that we usually consult.

If χ^2 tables are not available, the following relationship between the χ^2 and F distributions can be shown to exist and may therefore be used:

$$\chi_\alpha^2(m) = m/F_\alpha\,(m, \infty)$$

$$= m/F_{1-\alpha}\,(\infty, m)$$

where α = specified percent area in the upper tail of the curve.

Example 1

Find the 5% value for χ^2 with 10 degrees of freedom:

$$F_{5\%}\,(10, \infty) = 1.83$$

$$\chi_{5\%}^2\,(10) = mF_{5\%}\,(10, \infty) = (10)(1.83) = 18.3$$

This is exactly the value shown in the χ^2 table.

Example 2

Find the 95% value for χ^2 with 6 degrees of freedom:

$$F_{5\%}\,(\infty, 6) = 3.67$$

$$\chi_{95\%}^2\,(6) = m/F_{5\%}\,(\infty, 6) = 6/3.67 = 1.635$$

This is also exactly the value shown in the χ^2 table. (Note that since the probability level, 95%, desired is larger than 50%, we use the formula

$$\chi_\alpha^2(m) = mF_\alpha\,(m, \infty)$$

and the complementary level, $100\% - 95\% = 5\%$, in entering the F table.)

Mathematical Justification

The conversion between the Binomial and the F distributions used here is exact and follows from the fact

that both distributions can be expressed in terms of the incomplete Beta integral,

$$(1)\quad \beta\,(p;\,d,\,n-d) = \int_0^p \frac{n!}{(d)!\,(n-d-1)!}\,x^d\,(1-x)^{n-d-1}\,dx$$

If we let

$$(2)\quad x = \frac{(m_1F/m_2)}{1+(m_1F/m_2)}$$

$$(3)\quad d = (m_1 - 2)/2$$

$$n-d-1 = (m_2 - 2)/2$$

(4) $x = 0$, $F = 0$; $x = p$, F_p = value from (2) corresponding to $x = p$, then

$$dx = \frac{(m_1/m_2)\,dF}{[1 + m_1F/m_2]^2}$$

and the integral (1) becomes

$$(5)\quad \beta\,(p;\,d,\,n-d) = P(F \leqq F_p) = \int_0^{F_p} \frac{[(m_1 + m_2 - 2)/2]!\quad (m_1/m_2)^{m_1/2}\,F^{(m_1-2)/2}\,dF}{[(m_1-2)/2]!\,[(m_2-2)/2]![1 + (m_1F/m_2)]^{(m_1+m_2)/2}}$$

which is the probability integral for the F distribution as shown in Mood, *Introduction to the Theory of Statistics*, p. 205 (and elsewhere in text books on mathematical statistics).

The Beta integral, (1), can be evaluated (by integration by parts) to form the series:

$$(6)\quad \beta\,(p;\,d,\,n-d) = \sum_{y=d+1}^{n} \binom{n}{y} p^y (1-p)^{n-y}$$

But this is exactly the probability of obtaining $d + 1$ or more "defectives" in a sample of n items from a binomial universe with parameter p. Therefore, the transformations, (2) and (3), do in fact convert F distribution probabilities represented by (5) into binomial probabilities represented by (6).

Similarly, both χ^2 and Poisson probabilities can be expressed in terms of the incomplete Gamma integral:

$$(7)\quad \Gamma\,(np;\,a,b) = \int_0^{np} \frac{e^{-x/b}\,x^a}{a!\,b^{a+1}}\,dx$$

If we make the substitutions,

$$(8)\quad x = \chi^2/2 \qquad dx = d(\chi^2)/2$$

$$b = 1$$

$$a = (m/2) - 1,$$

$$x = 0,\ \chi^2 = 0;\ x = np,\ \chi_{np}^2 = 2np$$

we obtain

$$(9)\quad \Gamma\,(np;\,a,1) = P(\chi^2 \leqq \chi_{np}^2) = \int_0^{\chi^2} \frac{(\chi^2)^{(m/2)-1}\,e^{-\chi^2/2}-d\chi^2}{2^{m/2}\,[(m/2)-1]!}$$

which is the probability integral of the χ^2 distribution as shown in textbooks on mathematical statistics.

The Gamma integral, (7), can be integrated by parts to yield the series:

$$(10)\quad \Gamma\,(np;\,a,1) = \sum_{y=a+1}^{\infty} e^{-np}\frac{(np)^y}{y!}$$

which is exactly the probability of obtaining $a + 1$ or more "defects" in a sample from a Poisson distribution with parameter np. Therefore the transformations, (8), do in fact convert the χ^2 distribution probabilities represented by (9) into Poisson probabilities represented by (10).

SUPERVISOR'S CIRCLE

PAUL A. ROBERT, *Editor*

Gruen Watch Company, Time Hill, Cincinnati 6, Ohio

Engineering and Inspection

PAUL A. ROBERT, *Gruen Watch Company, Cincinnati, Ohio*

THE basic responsibility for producing a design which will satisfactorily meet the consumers' requirements at the intended cost rests with the design engineer, but there are so many technological areas involved in the engineering and manufacture of a product that it is only wishful thinking to expect the design engineers to have more than a casual knowledge of many important considerations that must be resolved.

There was a time when the design engineer was familiar with shop techniques and processes to the degree that he could visualize all the steps involved in the manufacture of his product, but the field of manufacturing engineering, quality control, etc., have grown so rapidly and the introduction of new materials, processes, and techniques has been so rapid that he must now rely on others to supply him with information, advice, and guidance in designing a new product.

As machines have become faster and more complex, tolerances have been reduced and many of the refinements which were disregarded in

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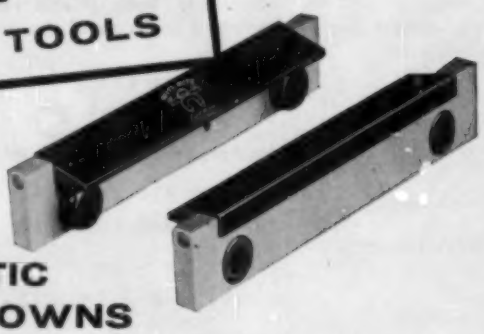

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It is surprising how many of these "tremendous trifles" still exist in our shops and it behooves the inspection manager to search out these areas of possible misunderstanding and get a definite set of rules and practices established.

To illustrate a few of these:

1. The dimension on a finished part should include all plating, anodize, or other surface treatment, as well as the growth or shrinkage that takes place in heat treatment. Is it the practice in your shop to manufacture parts so that these variations are taken into account when the parts are machined? If the prints and specifications to which you work to in the shop permit the full tolerance before plating or heat treating, there is a good possibility that some of the finished parts will be out of tolerance.
2. The Military Standard on Dimensioning and Tolerancing, MIL-STD-8A, states: "The limits indicated by these methods (unilateral, bilateral and limit dimension) restrict not only size but also geometric characteristics such as parallelism, roundness, perpendicularity, eccentricity, etc. Specifying limits indicate that the entire surface concerned must lie within limits, not merely a point on the surface."

   This is what might be termed a theoretical concept that is seldom found in actual practice. Shop or engineering standards developed by industry tend to recognize the exceptions that make it practically impossible to apply the above rule, as written, to all situations.

   For example, take a simple angle bend as shown in Fig. 1. If the above definition is to be properly interpreted, the designer in specifying a tolerance of 0.050 + 0.002, −0.000 has constructed an envelope 0.002 larger than the basic theoretical shape that must contain any error in flatness of either

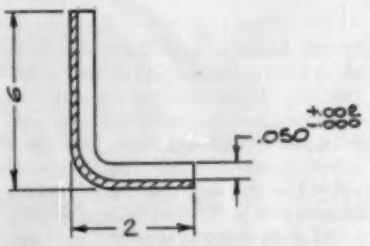

Figure 1

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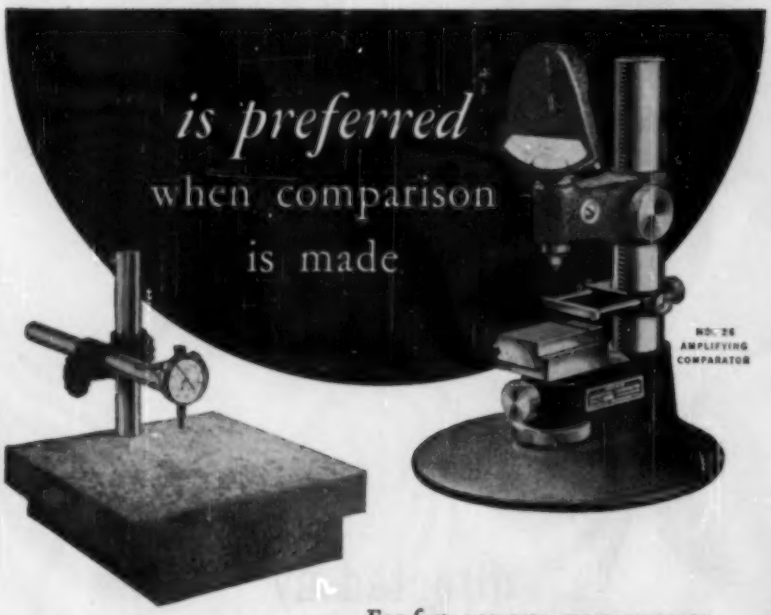

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leg, an error in squareness of the form, any reduction in cross section at the bend, as well as any variation in thickness of the original material. What's wrong with this? From the point of view of the designer, nothing, but from the point of view of the man in the shop, there are several things wrong:

(1) The tolerance is not related to the length of the legs, and anyone familiar with manufacturing practice knows that any variation in forming this piece increases as the length of the legs increase.

(2) The supplier of the material is entitled to take all of the tolerance in producing the stock for this part and probably will. This would leave no tolerance for the punch press.

(3) The thickness, right at the bend, is something less than 0.050 but a strict interpretation of the above definition would not permit anything below this dimension.

(4) Thickness is customarily measured with a two anvil instrument such as a micrometer, or snap gage. To combine this check with the variation in flatness of each leg, and the variation in squareness of the bend, and to state definitely that the entire part would be contained in a theoretically shaped contour 0.052 wide is practically impossible.

This tendency on the part of the engineers to describe an idealistically conceived envelope as containing the part, is natural because it simplifies their problem of design. But it does not make for good quality control because specifications of this nature cannot be met practicably in the shop with the result that there is frequent argument and disregard of blueprint requirements and engineering standards. It is most important that those of us who are interested in seeing realistic specifications established which are both measurable and attainable by the shop, carefully review the practices of dimensioning and tolerancing in our organizations to see that what we have set up is both understood and practiced.

3. If at all possible, the dimensions on a part should originate from a

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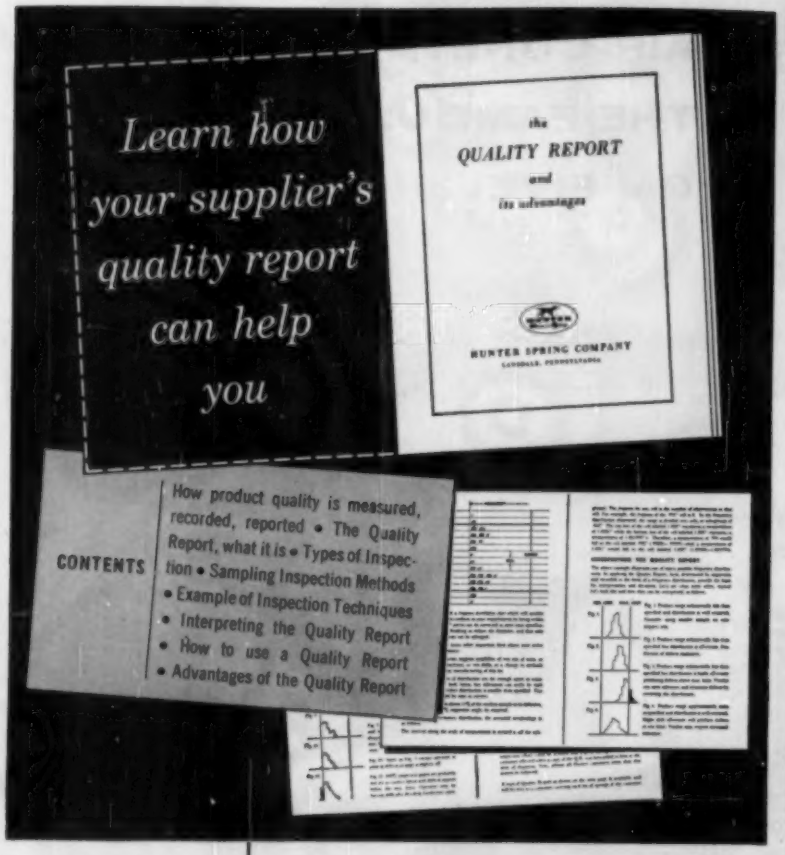
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single horizontal and a single vertical surface. Dimensioning from real surfaces that can be used as basic locations for both machining and inspection simplifies manufacturing and reduces the possibility of error due to an accumulation of tolerances.

While it may be advantageous for the designer when considering only function to work around theoretical centerlines in making his layouts, it imposes a terrific hardship on the manufacturing organization if they have to machine parts dimensioned in this manner.

To get around this difficulty, it is sometimes desirable to create locating surfaces for that purpose alone. Two holes, for example, can be used to create a centerline and serve as a means of locating the part for machining. Castings are sometimes machined from pads that have no other function than to locate the part for machining and inspection.

From the point of view of quality control, it is most important that the functional requirements of the product and the method of manufacture and inspection both be reconciled by the dimensions and tolerances appearing on the print.

4. All dimensions which are functional or must be controlled should appear on a print. It should never be necessary for either an operator or an inspector to compute a dimension. On the other hand, only one set of dimensions should locate any particular surface or point on a part.

5. It is sometimes necessary to use basic, reference, or datum dimensions. These dimensions appear on prints for setup, information, or for use in connection with another dimension which does have a tolerance.

   These dimensions are never the basis for acceptance or rejection of a part.

6. At one time it was not unusual to see such indefinite terms as "smooth" or "grind" to describe a surface, or "broken" or "sharp" to describe a corner. The inspector was always faced with the decision "How smooth is smooth" and of course, this resulted in differences of opinion. In general, such meaningless notes on prints are a thing of the past but the chief inspector should always be alert for this type of specification. There will always be some areas

where the problem will exist. One such area is burrs. It is a general practice in most shops to leave it up to the Inspection Department to determine where burrs, rough edges, etc. can be tolerated. In addition to the functional requirement there is always safety, plating buildup, etc. to consider in evaluating the importance of burrs.

7. The tolerances on non-functional dimensions has always been an interesting subject of discussion. Everyone knows there are numerous dimensions on any part that are there for the guidance of the tool designer and toolmaker in providing the tools, and they could vary substantially and not affect function.

Most of the literature suggests that the shop be given all of the tolerance possible. This philosophy forces the designer to consider **every** dimension, which he is most reluctant to do, and which may be waste of time and effort. For example, suppose a designer has decided to put a "peep hole" in a side frame so a repairman can look in and observe a timing mark, what tolerance should be put on this hole?

Maybe the hole can be 0.500 ±0.125 and not affect the function of the part, but it does not benefit the shop to have so large a tolerance. There is a limit of process variability associated with every process and nothing is gained by specifying larger tolerances.

Some years ago the author investigated the effect of tolerance on the drilling and piercing costs in a large plant where he was employed. It had been the practice of designers to specify ±0.003 −0.000 on all non-critical holes under 0.250, such as clearance holes for screws, oil holes, etc. A study of the savings that might be effected by relaxing this tolerance was undertaken and it was found that the cost of tool maintenance could be reduced, the expected life of the tool increased, and the operation could be speeded up if a tolerance of ±0.005 −0.003 was specified instead. The savings in one plant alone amounted to over $300,000 per year.

Rather than instruct designers to give the shop all the tolerance possible on a particular dimension, it is suggested that we establish for the various processes in

(Continued on page 68)

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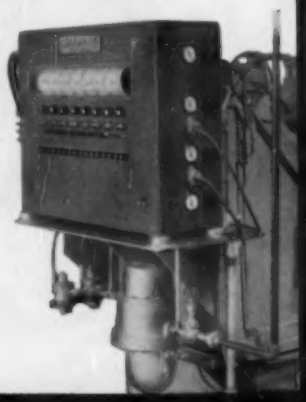

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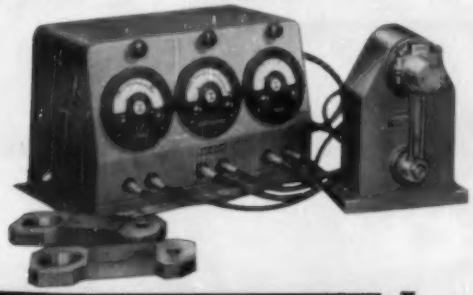

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(Continued from page 65)

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It is most important, if the relationship between Engineering and Manufacturing is to flourish in an atmosphere of mutual respect, that the needs and desires of each be respected by the other.

Quality Control can serve the shop by evaluating specifications, standards, and design practices in terms of their practicality and engineering by seeing that the objectives of the designer are met in the product.

BOOK REVIEWS

W. D. Baten, Editor

26 University Drive, East Lansing, Mich.

QUALITY CONTROL THROUGH STATISTICAL METHODS by Norbert Lloyd Enrick, published by Modern Textiles Magazine and Rayon Publishing, New York, N. Y., 1954, 71 Pages, 8 × 11, paper bound, price $2.00. Reviewed by O. P. Beckwith.

This handbook, as stated by the publishers, is a revised and enlarged version of a series of articles appearing in Modern Textiles Magazine during 1953 and 1954. It is written specifically for textile manufacturers.

The book covers the application of elementary statistical techniques in the presentation and interpretation of textile manufacturing data. Measures of variability, the comparison of variation, analysis of variations, control charts, sampling plans are covered. A section on management aspects of quality control and a guide to further literature is included.

The aim of the author is to present applications of simple statistical methods covering a wide variety of specific textile manufacturing problems of the kind encountered throughout the industry. No attempt is made to develop the statistical theory on which the applications are built but sufficient explanation is given to provide the reader with an intelligent understanding of what is being done.

The handbook is excellent and quite comprehensive in its treatment of the application of statistical methods in the various branches of textile manufacturing. It is especially fitted for those who are interested in pursuing the subject and who are self-taught in elementary statistics or have taken the short courses in quality control sponsored periodically by colleges and technical schools. A manual complementing this handbook is "An Outline of Statistical Methods for Use In The Textile Industry," by A. Brearly and D. R. Cox, Wool Industries Research Association, Torridon, Headingly, Leeds 6, England, January, 1949. This devotes more content to theory and less to application than the Modern Textiles Handbook.

Without detracting from the merit of the handbook, rather to emphasize the need in the hopes that it will be met at some future time by the author, the omission of applications describing the planning of factory tests is pointed out. Production people are constantly running tests to determine whether a new piece of equipment is better than the old, whether new yarn weaves or knits better than the old, whether a new method is better than the old, etc. Undoubtedly, the advances in the field of design of experiments have developed enough knowledge so that some simple principles and techniques could be prepared for the production man to improve his planning of tests. If the reasoning behind the

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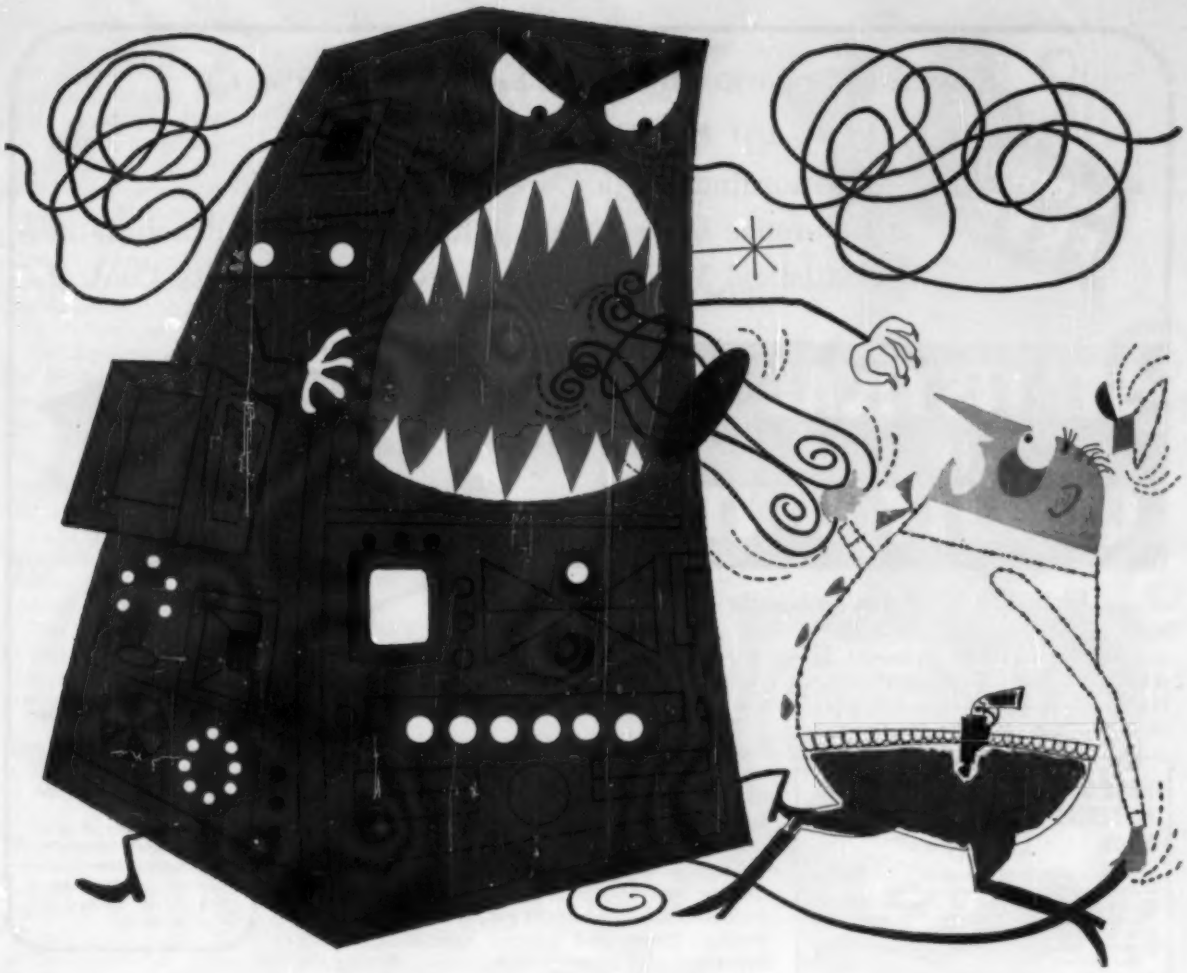

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Analysis of a Process Subject to Sporadic Changes in Cause
System and Systematic Difference among Categories
Specifications, Parameters and Statistics
Use of Control Charts for Variables during Production
Selection of Statistic and Computational Procedures
Operating Characteristics of Control Charts for Variables
Comparison of Process Control Plans
Systems of Frequency Curves for a Continuous Variable
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Chapters 13-29 cover chiefly process control. In addition to extensive use of control charts, various other statistical methods are presented. The author includes analysis of variance, likelihood ratio tests, chi-square, autocorrelation and many others. The final eleven chapters are devoted to a thorough discussion of product control (acceptance sampling).

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Randomized Block Design and Latin Squares could be simply expressed and illustrated with specific examples so that the production supervisor could grasp the object of the techniques, it ought to insure a better running of production tests. While the production man may never be able to do a statistical analysis of the data collected from the tests, his common sense interpretation of the results of a properly planned trial would result in a great improvement in their conduct.

Quality Control Through Statistical Methods is recommended for the textile quality control and production man.

CHANGING PATTERNS AND CONCEPTS IN MANAGEMENT, General Management Series, Number 182, American Management Association, 1515 Broadway, Times Square, New York 36, N.Y. Reviewed by Hugo Lundberg, Jr.

This pamphlet is composed of four papers read before the General Management Conference of the American Management Association.

The paper that is probably of greater general management interest is the one on "Developing Patterns of Management: II," by Rensis Likert, in which he describes the concept of the "linking pin" function in management which is a team conference approach to management problems. More companies today are replacing the old "man to man" pattern with the team conference. The team conference method certainly gives a broader approach to problems, however, it does not relieve the head of the management team from making and carrying out the final decision. It is worthy to note that Mr. Likert is Director of the Institution of Social Research at the University of Michigan and certainly people who are interested in management will obtain a new viewpoint on management organization by this eminent sociologist.

IMPROVING THE CALIBER OF COMPANY MANAGEMENT, Today's Tools and Techniques, General Management Series, Number 183, American Management Association, 1515 Broadway, Times Square, New York 36, N.Y. Reviewed by Hugo Lundberg, Jr.

The above pamphlet contains six papers read before the General Management Conference of the American Management Association.

A new look at the question of standards is given by William C. Treuhaft, President of the Tremco

(Continued on page 75)

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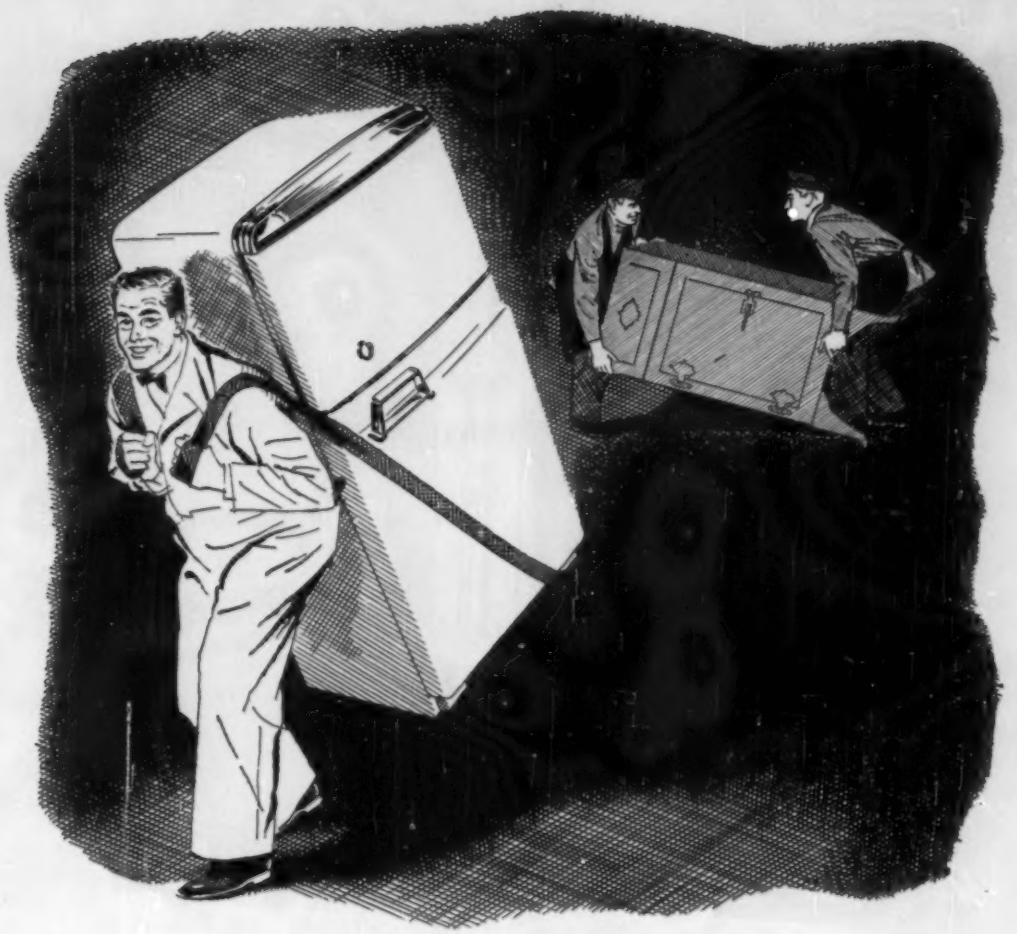

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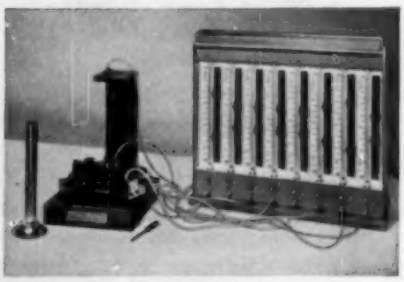

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(Continued from page 71)

Manufacturing Company, Cleveland, Ohio, in his experience with the executive standards of performance. This is a new field in which he gives his experiences in determining standards for his sales organization.

Another paper which would be of general interest to management people is "The Return-On-Investment Concept as a Tool for Decision Making" by Charles R. Schwartz, in which he relates "the return on investment formula" to some of the business problems facing management today.

While space will not permit a detailed review of each of the papers in these two pamphlets, I believe that all of the papers would prove very interesting to members of management and also students of management's problems.

QUALITY CONTROL FOR PLASTICS ENGINEERS, edited by Lawrence M. Debing, published by Reinhold Publishing Company, New York, 1957, 142 pages, price $4.95. Reviewed by A. E. Wylie.

This small book provides an excellent introduction to statistical quality control for the plastics industry. It contains chapters on frequency distributions, control charts, sampling inspection, process capability analysis, significance tests, and experimentation. A most important feature is the inclusion of the large number of illustrations of statistical techniques now in use in plastic manufacturing.

Presentations of the nine authors are rather brief. In spite of this the selection and coverage of topics provides the man with engineering abilities sufficient material to apply statistical analysis in his work. Since most users of the book will find a need for more detailed exploration of techniques, references are given for each topic discussed. Perhaps, a more extensive reference list and a bibliography of articles on plastics quality control would be helpful.

Wide use of the information in this book will lead to quality control at a high level of performance.

Local Section News

"... BUT NOT FORGOTTEN"

ALBUQUERQUE At the March meeting held at Mitchell Hall, University of New Mexico, G. J. Lombardi of the Sandia Corp. led the education session in a discussion on sampling, its use in industry, and the deviation of attribute sampling plans. C. R. Quillen, Ford Motor Co., was the guest speaker. His topic, "Application of quality control to the automobile industry," covered the industrial accomplishments which management expects quality control to produce and the quality control organization which can meet these demands through product acceptance and assurance on a statistical basis. A lively question period followed the talk.

ALLENTOWN-BETHLEHEM On Mar. 13 the regular meeting was held at the Sigma Room of Walp's Restaurant, Allentown. Dr. Acheson Duncan, of Johns Hopkins, addressed an overflow audience on "The design of control charts" with special emphasis on the economics connected with proper design and application of $\bar{X}$, R charts. The section saluted chairman Doug Adams for past service and wished him success on his new assignment in Chicago.

BINGHAMTON The March meeting was a very successful all-day clinic sponsored with the Scranton-Wilkes-Barre, Syracuse, and Corning-Elmira sections.

BUZZARDS BAY James A. Mitchell, Tennessee Eastman Co., Kingsport, Tenn., was the main speaker at the Mar. 12 meeting. His subject was "Control of the accuracy and precision of industrial tests and analyses." Illustrating his talk with colored slides, he demonstrated the use of control charts in conducting chemical tests.

Shaw Goldthwait of the Collyer Insulated Wire Co., Pawtucket, R.I., who has been acting as the section's representative to the New England Council, reported on a meeting he attended in Bridgeport.

CHARLESTON The March meeting featured an address by Charles A. Bicking, Carborundum Co., who spoke on "Installing quality control in a going industry." This was another of the series of talks on the practical application of statistical quality control and was well received by the members present.

CHICAGO A panel discussion on SQC was held by the Calumet sub-group at Joe's Thornbridge Inn, Thornton, Ill. The members of the panel related applications of statistics to specific laboratory testing procedures in their plants. The psychological effect of statistical experiments on technicians was described.

On Mar. 26 A. H. Benscoter, director of QC, Permaglass Div., A. O. Smith Corp., spoke to the Fox Valley sub-group at Club Arcadia, St. Charles. Mr. Benscoter discussed the application of QC to metal working industries.

Variations that are available within sampling procedures were discussed at a meeting sponsored by the Basic Educational Committee. Quality control director W. Lieberman of Pentron Corp. reviewed this subject.

A meeting jointly sponsored by the section and the Electronics Division was held at the Navy Pier facilities of the University of Illinois on Mar. 27. The meeting consisted of a panel discussion of the subject "What does management expect from the quality control department?"

A ten-week short course in quality control is now being conducted by the Fox Valley sub-group. Classes

(Continued on page 78)

ASQC CONVENTION EXPOSITION CHART

AMERICAN SOCIETY FOR QUALITY CONTROL

11th Annual Convention • Masonic Temple • Detroit, Mich. • May 22-24, 1957

....MEMO

To: All Members and Friends of ASQC

From: ASQC Convention Planning Committee

SOME TIME AGO you received your brochures describing the outstanding 11th Annual Convention in Detroit on May 22-24. The April issue of *Industrial Quality Control* also carried a registration form for your use. It is not yet too late to register in advance for this important event. Surely, you can't afford to miss it.

EVERY YEAR, the Convention offers an unexcelled opportunity to learn the latest thinking and developments in the quality control and allied fields. Its program is more ambitious and informative than the ones offered by many other technical societies of considerably greater age and larger membership. Nowhere else can you obtain, in one concentrated package, such a variety of pertinent, timely material of vital import to you in your own job.

IN ADDITION to the technical program, the most important phase of our Convention activity, you will find the many other features and services for which your Conventions have become justly famous over the years. The exhibits will be unusually diversified and helpful. The plant tours will satisfy your craving to know how that key factor in American life, the automobile, is born—as well as giving you an opportunity to visit an exceptional chemical operation. Your Society Divisions will inaugurate a new custom of dinner meetings.

ALL OF THESE activities are calling YOU to Detroit — the complete Ladies' Program is calling your favorite companion to an event-filled activity every whit as exciting as yours.

COME, THEN, to Detroit for your Convention. Your Quality Control friends from all over the world are looking forward to meeting with you again there. Register now! Bring your wife and family — and pass this on to your boss — he'll want to make the trip with you.

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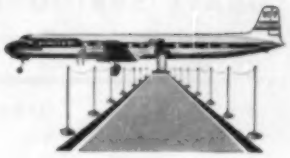

*"Red Carpet" is a service mark owned and used by United Air Lines, Inc.

(Continued from page 75)

are held at the St. Charles High School on Tuesday nights at 6:30 pm. The program will cover the application of SQC techniques in work areas such as, incoming material, new designs, process control, product control, and special studies.

CINCINNATI The regular March meeting featured Dr. Harry A. Smith, Proctor and Gamble, on "Sequential Analysis." Dr. Smith gave many helpful tips on the use of this quality control method to improve the efficiency of gathering data. The coffee talk was enlivened by the performance of Bill Allen, magician.

Certificates for the successful completion of the spring educational course have been awarded to 35 students covering all courses.

CORNING -ELMIRA On Mar. 12, L. A. Seder spoke to the largest meeting of the year on the subject "Who is responsible for quality." A large turnout of production personnel visited the meeting to learn of their responsibility with respect to quality.

DAYTON March was a big month for the section. We are pleased to say that our second all-day conference was a success. The attendance numbered 147 which was an increase over our first conference and is an indication that more and more industries are becoming interested in quality control.

The second meeting for the month was held on Mar. 28. The speaker for this meeting was J. Fred Verigan of the Crown Cork and Seal Co.

DELAWARE The Mar. 7 meeting on the subject of work sampling brought out the largest attendance of any meeting so far this season. The scheduled speaker was unable to be present but the subject was very ably handled on short notice by Richard C. Dumene of the construction division of Du Pont's Engineering Department..

DENVER Hugh Campbell, manager of quality control for the Denver Division of Martin Aircraft, spoke on "Quality control at Martin" at the Mar. 13 meeting. Mr. Campbell stressed the importance of cooperation and communication in setting up SQC programs, particularly in the Martin Company with its large numbers of sub-contractors and many intricate components required in its products. Guests included representatives of Martin and other Denver concerns and Mr. Smith and Mr. Taylor of the Statistical Department of British Overseas Airways in London.

GEORGIA The Atlanta group met on Tuesday Mar. 26, for a talk on "High-low quality chart for individuals" by E. G. Field, consulting management engineer. A little theory was used in setting the advisory limits, and three cases were examined in comparison with the conventional $\bar{X}$ and R charts.

GREATER MUSKEGON Thirty-five members gathered on Mar. 14 at Bill Stern's Steak House to hear Professor Kraft of Michigan State University. His topic was "The basic fundamentals of quality control." Merril Bailey of Anaconda outlined plans for a QC training course to be presented in the spring or fall in conjunction with the Extension Service of Michigan State. Consensus of the group present indicated that a course in the early fall would be more advantageous.

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HAMILTON-MIDDLETOWN The March meeting was a plant tour through Armco Steel at Middletown. A fine dinner was provided by Armco to the 52 people who attended. The dinner was followed by a three hour tour of the plant through the open hearth blast and finishing departments.

HAMILTON, ONT. The regular March meeting was held at the Canadian Westinghouse Auditorium. Ben Lloyd, management consultant with Leetham-Simpson and Co., Montreal, Quebec, was the featured speaker. His subject was "Quality control and cost control." Mr. Lloyd's talk pointed out the savings which could be realized through the application of SQC.

HARRISBURG The largest attendance in the history of the section, 162 members and guests, heard one of the finest talks ever presented to the section on Mar. 6 at the Schick Razor plant in Lancaster when Miss Bonnie Small of Western Electric Co., gave us her presentation of "A practical training program for QC personnel." It is quite easy to see why she is a leader in the field of training for quality. A guided tour of the new Schick plant was the climax of a very enjoyable and informative evening.

KANSAS CITY H. R. Harrison, quality control manager of the Collins Radio Co., Cedar Rapids, Iowa, was the guest speaker at the March meeting. His subject, "What statistical quality control has done for Collins Radio Co.," introduced the documentary and charted evidence of the values of SQC. Prior to the dinner a clinic session heard Phillip Fleming of Bendix Aviation explain the application of the various plastics in industry. A display was used to illustrate the advantage of the different types. After the meeting, the section was invited to view a display arranged by John Cobb, past president of the section. The display consisted of charts, map, and a clay build-up of a terrain map. The terrain map depicted the amount of fallout concentration over a three month period estimated from daily weather reports of wind direction and velocity. The display has been very popular in area Civil Defense activities.

LINCOLN The section was guest of the Goodyear Tire and Rubber Co. on Mar. 8. Following a fine dinner provided by the company, 48 members and guests were very impressed by the results of a "Progress report on the use of statistical quality control" at the Goodyear plant in Lincoln. Mr. P. Murphy of Goodyear delivered the report and at its conclusion invited questions from the audience pertinent to SQC procedures in use at the Lincoln plant.

LOS ANGELES The March meeting discussed statistical cost controls. The clinic, led by Dr. Harry G. Romig of Summers Gyroscope Co., emphasized the fact that cost is a most important feature of any item, and considered the factors entering into preparation of unit costs of materials.

MEMPHIS The March meeting was held at Plough, Inc. The speaker was Dr. David S. Chambers from the University of Tennessee, Knoxville, and a consultant in quality control and statistics. His subject was

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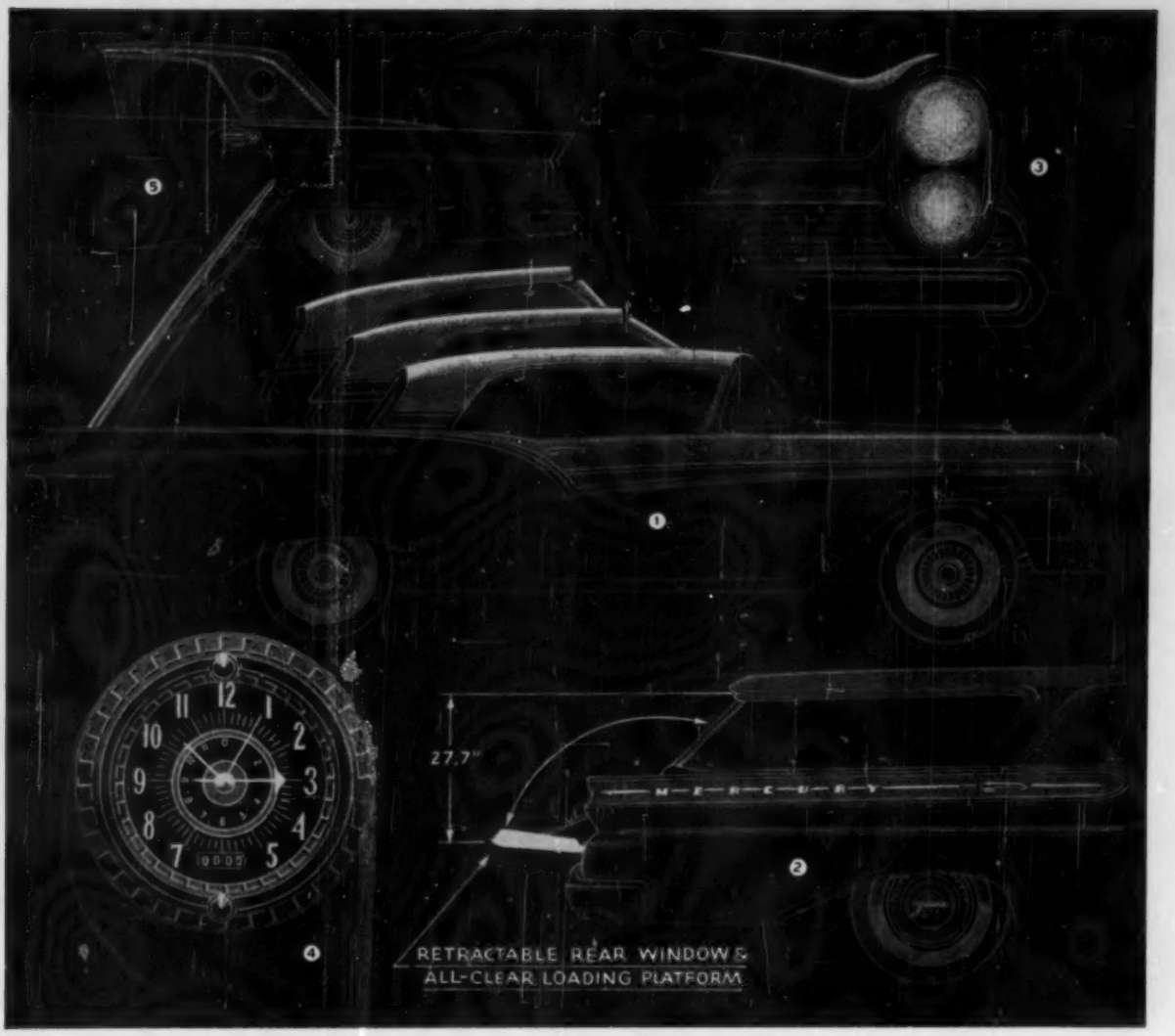

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❷ And there's the disappearing back window on Mercury's completely new line of station wagons! By remote control, if you like, this window lowers into the tailgate. This eliminates the liftgate . . . makes an "all clear" loading platform when the tailgate is down.

There are more examples: ❸ the Quadra-Lite Grille on the Lincoln . . . the car that introduced dual headlamps to the American Road, ❹ and the Average Speed Computer on Mercury's Turnpike Cruiser . . . an instrument which, among other things, lets you calculate your average speed at any point on a trip. ❺ Then there's the distinctive Thunderbird, the only successful personal car in America . . . or the Continental—the ultimate expression of automotive styling.

We have over 50 years of car-building experience—and a determination to stay young-minded. We think these cars prove it.

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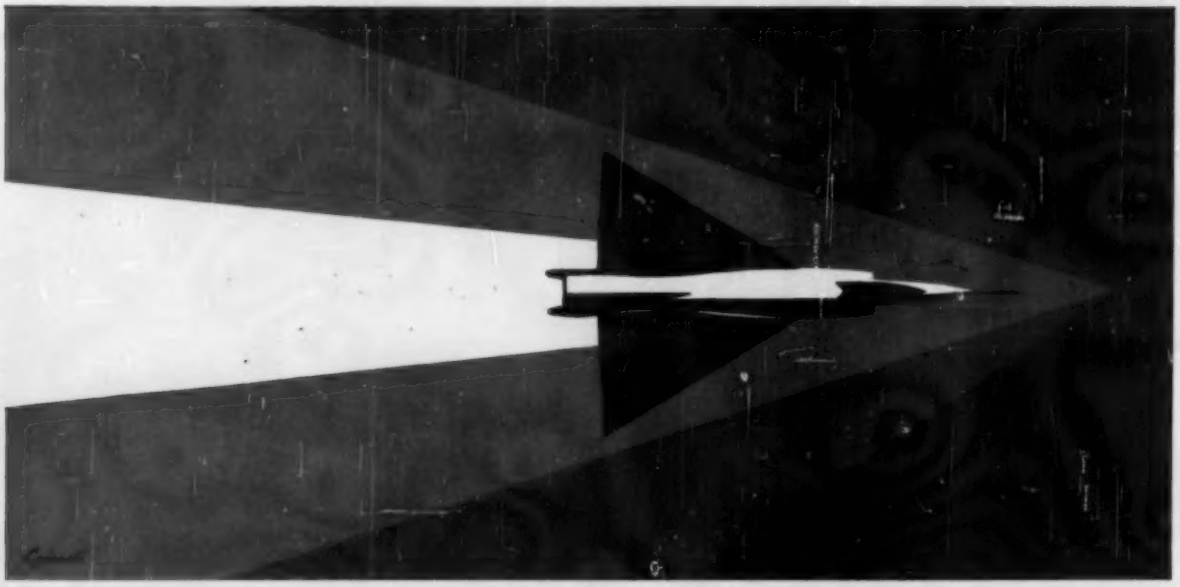

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"Control of the looping operation—a textile application." By means of films and charts he showed how by simple statistical procedures he was able to lower the percent defective of this particular textile operation from a 4.8 percent level to a level of less than one percent.

A slate of officers was reported by the nominating committee and the secretary was instructed to draw up a ballot to send to all of the section members.

MID-HUDSON F. J. Berkenkamp of General Electric Co. spoke on "Quality costs—a powerful management tool" at the March meeting. Mr. Berkenkamp stated that there were three general areas where the inspection dollar could be spent. These were prevention, investigation, and actual inspection.

MILWAUKEE The annual clinic was larger than in the past years; over 180 participated. The section made an attempt to promote administrative applications through three sessions. This addition to our usual sparkling program proved to be a success.

MONTREAL The March meeting was held in conjunction with the certified general accountants. Claude Taylor of Trans Canada Air Lines gave a very interesting talk on the "Statistical approach to management controls." This was the first time that such a topic had been given and judging from the lively question and answer period the meeting was a tremendous success.

PORTLAND The success of the first attempt by the section to play host to the Northwest Conference was indeed gratifying to the members who worked so hard on this project. Registrations totaled 125, and included representatives of industries in Oregon, Washington, Idaho, and northern California.

In addition to the presentation of papers and discussions by outstanding men in the quality control and statistical fields, a pre-conference training session was well accepted by some 50 registrants. Barnard E. Smith, Oregon State College, and Donald Hancock of Jantzen, Inc., were the training session instructors.

RACINE "Foundry quality control" was the subject discussed by James Barrabee of International Harvester. Mr. Barrabee, guest speaker at the Mar. 11 meeting, really impressed the section with his knowledge of foundry problems and remedies and their interest was shown in the manner in which some groups corralled Mr. Barrabee after the meeting adjourned. We certainly hope this gentleman visits us again next season.

RHODE ISLAND Fred C. Schulze spoke at the Mar. 21 meeting. His subject was "Management and scope of statistical quality control."

ST. LOUIS The section had the best turnout yet for this year to hear Roy Wylie, Minneapolis-Honeywell Regulator Co., Micro-Switch Div., Freeport, Ill., who spoke on "Analysis of variance" at the Mar. 22 meeting.

The annual awards for the most outstanding paper on quality control from the two local universities were also presented at this meeting. Frank Ehlen, St. Louis University, was given a $50 award for his paper "Science and art of reliability" and Tom Regh, St. Louis University, with his paper "Reliability—its meaning" being judged a close second, was given a year's membership in the Society.

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SAN BERNARDINO Dr. O. B. Moan was the featured speaker at the March meeting held at the Chuck Wagon in San Dimas. His subject "Non-parametric statistics" was enjoyed by all and evoked a lively question and answer period following the presentation.

SAN FRANCISCO BAY AREA Irvin E. Schiesel, national treasurer of ASQC, spoke to the section on Mar. 18. Eighty-five members and guests attended the dinner and heard Mr. Schiesel speak on "Cost analysis by control chart methods." Mr. Schiesel's talk was aimed at both quality control and accounting personnel. He presented methods for judging whether or not the cost of additional quality improvement is worth the improvement attained. Properly presented data may mean the difference between the enthusiastic or indifferent support of a quality control program by company management.

SEATTLE Al Block of the Dynamic Research Association presented a very interesting discussion of automation and its effect on a quality control program at the Mar. 12 meeting.

SOUTH BEND -MISHAWAKA Dale Lobsinger, President of ASQC, addressed the section on the subject, "QC in the Airlines." He stressed the fact that SQC could save money for an organization by reducing errors. In the above photo, Mr. Lobsinger is shown discussing his speech with chairman Robert Fitzgibbons (left) and vice chairman Fred De Ferbrache, Jr. (right).

WINDSOR The application of statistical quality control to industrial problems was the theme of the talk by Bernard N. Au France, an inspection engineer with Associated Engineers, Ltd. at the March meeting. He featured the recording and analysis of warranty claims which proved to be very popular with those present, since many were from the automotive industry.

WINNEBAGO Thirty-eight members attended the March meeting which was held at the Appleton Elks Club. Larry Neuman, supervisor of quality control at the Miller Brewing Co., traced the charting methods used in controlling beer manufacture and demonstrated how they have become the excellent tools for product uniformity and improvement. From a humble beginning, made up of three people, the statistical quality control department of Miller Brewing has grown to a staff of 49.

Dr. Carl Noble described and illustrated the simplex method of linear programming at the training session which preceded the meeting.

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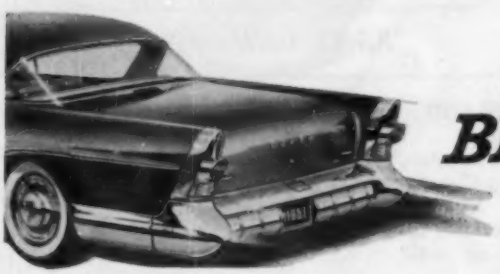

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"... CAST THEIR SHADOWS BEFORE"

CINCINNATI The social highlight of the year will be the combined dinner dance of the Cincinnati and Hamilton-Middletown sections to be held on June 14 at the Greenhills Country Club. The feature of the event will be the installation of the new officers for the coming year of both sections.

CORNING -ELMIRA Present plans call for the closing meeting of the year to be in the form of a social event on June 8. Arrangements for this meeting are under way and will be announced at a later date to the members.

DELAWARE The May meeting of the section closes the formal schedule of meetings for the season but the executive committee will continue to meet regularly throughout the summer to carry on the activities of the section without a break and to complete plans for the coming season.

GEORGIA The Atlanta group will meet on Tuesday, May 28, for a talk on the practical "Use of MIL-STD-105A" by E. B. Windisch, chief inspector for the Inspector of Naval Material, Atlanta.

GREATER MUSKEGON The section will meet May 23 with the Muskegon Manufacturers Association at Bill Stern's Steak House. It is an annual affair and a joint meeting with the Cost Accountants, Western Michigan Chemical Society, Purchasing Agents, Safety Directors, and Personnel Administrators groups. This meeting concludes the QC program for the 1956-1957 season.

HAMILTON -MIDDLETOWN The social highlight of the year will be the combined dinner dance of the Hamilton-Middletown and Cincinnati sections on June 14 at the Greenhills Country Club. The feature of the event will be the installation of the new officers for the coming year of both sections.

HARRISBURG The June 5 meeting will be somewhat of another first for our section. The evening will begin with a tour of the Glatfelter Paper Mill in Spring Grove, Pa. including the new building just recently opened in which they have one of the largest paper making machines in existence. After the tour we will reconvene at Glatco Lodge for an informal evening of fun and food. At this time we will have the drawing for a number of prizes to be given to those members having perfect attendance for the year.

KANSAS CITY The June 12 dinner meeting will feature convention reports by the members who are going to attend the Annual Convention in Detroit. The meeting will be held at the Blue Hills Restaurant.

LOS ANGELES The June meeting will discuss the subject of "Providing assurance for management's quality goals." The two speakers will be Paul E. Bruce and H. Dean Voegtlen, both of Hughes Aircraft Co.

MID-HUDSON The annual social evening will be held at Germania Hall. Keep June 4 open and plan on being present to enjoy the fun and relaxation.

MONTREAL The annual dinner meeting of the section will be held on June 19.

ST. LOUIS Since the May meeting date conflicts with the Annual Convention, the spring party and installation of new officers which usually takes place at this time will be held June 1. This party, being new and different in the line of entertainment for the section, will be one no one will want to miss.

SAN BERNARDINO The June 13 meeting will be held at the Chuck Wagon in San Dimas. The featured speaker for the evening will be H. I. Matosoff of Kwikset Locks, Inc., Anaheim, whose subject will be "A total quality control program."

SOUTH BEND -MISHAWAKA A one-day conference is being planned by the section for presentation in the fall. Wayne Miller is to be the chairman of the event.

"AS YE SOW . . ."

CLEVELAND Everyone interested in quality control in the northern Ohio area is cordially invited to attend the Fourth Annual One-Day Conference in Cleveland. The date for this year's conference is Nov. 5 and it will be held at the Hotel Carter. A fine program has been planned which should be of interest and value to all.

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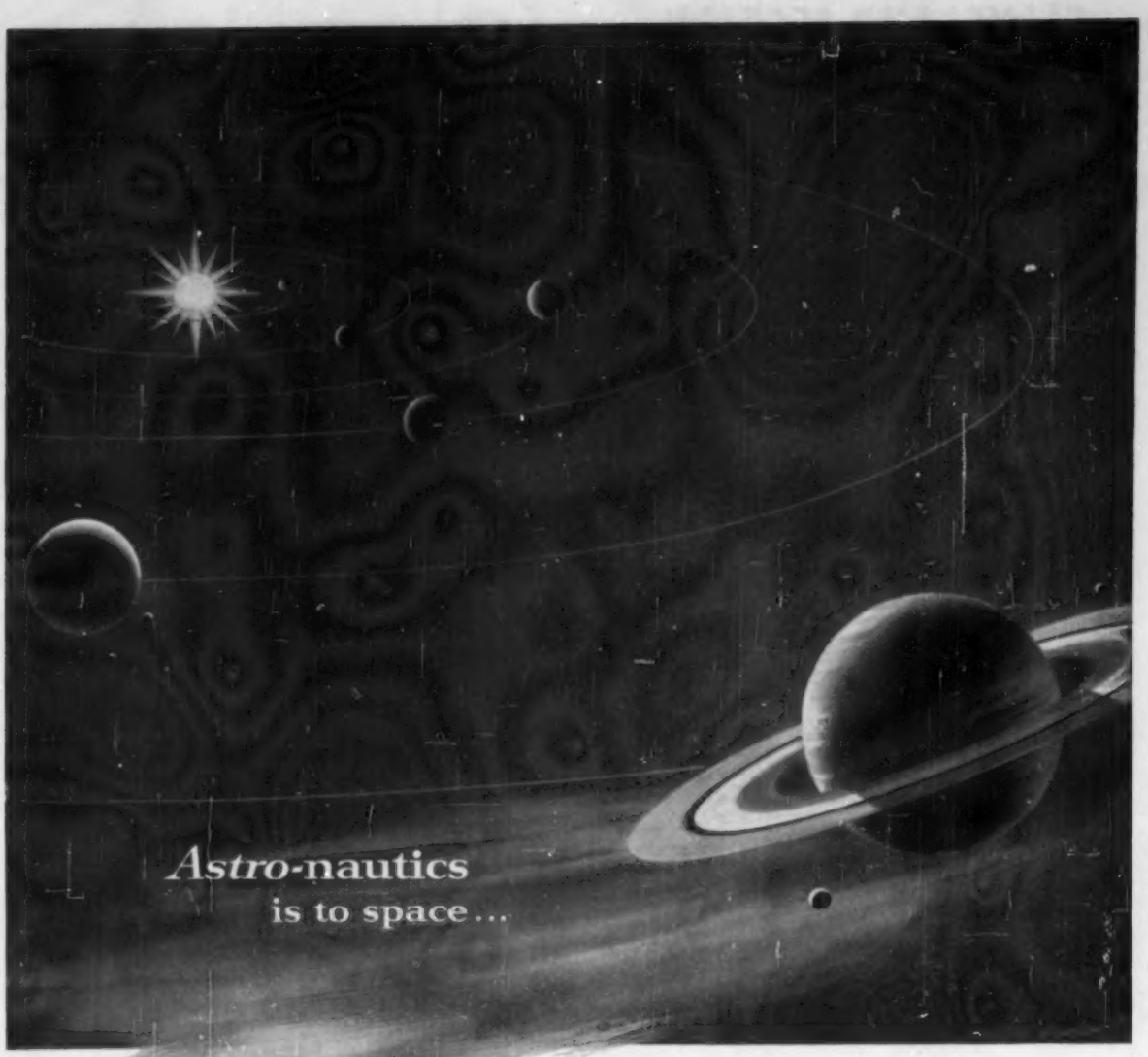

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STATISTICAL METHODS IN INDUSTRY—UCLA A course devoted to "Statistical methods in industry" is to be sponsored by the department of engineering, University of California, Los Angeles, in cooperation with the University Extension and the Los Angeles section of ASQC. This is a full-time program, from 8 to 5 for ten days, during the period Aug. 5-16.

Participants may register for one of two concurrent courses—a basic course in quality control by statistical methods or an advanced course in industrial statistical methods. In addition, a series of general lectures for all participants will be presented on such subjects as reliability in industry, statistics in research, standards and gaging in inspection, quality control procedures, organizations, and reports to management.

The $250 fee for the course covers tuition, books, supplies, ten luncheons and one dinner.

Included in the staff will be Prof. Irving Burr of Purdue University and Prof. Lloyd Knowler of the State University of Iowa as well as other distinguished representatives of government, education, and industry.

For further information write Prof. Edward P. Coleman, Coordinator, Statistical Methods in Industry Course, Department of Engineering, University of California, Los Angeles 24, Calif.

UNIVERSITY OF MICHIGAN The University of Michigan has scheduled its tenth annual ten-day intensive course in quality control by statistical methods for Aug. 19-29, on the campus in Ann Arbor. This is a first course for executives and supervisory personnel; it is practical and mathematically non-technical. It includes the standard control charts and sampling acceptance plans together with other basic techniques.

Instruction includes lectures, demonstrations, practice sessions and conferences. The staff will include Professors I. W. Burr, Purdue University; E. G. Olds, Carnegie Institute of Technology; and C. C. Craig and E. C. Yehle, both of the University of Michigan. The fee will be $125.

Please address inquiries to the course director, Prof. C. C. Craig, 106 Rackham Building, Ann Arbor, Mich.

MOTION AND TIME STUDY The University College and the Department of Industrial Engineering of Washington University will offer a nine day intensive course to be held June 5-14 in air-conditioned rooms at Washington University, St. Louis, Mo.

This course is intended for personnel desiring a basic and overall introductory course in motion and time study. In addition the new concepts and techniques presented will help present analysts to review and to gain necessary new information.

The procedure to be used in presenting the material will center around the actual "doing" of the work. Lectures will be kept to a minimum while problems, discussion, and questions will occupy most of the time.

The teaching staff will be comprised of Prof. Gerald Nadler, Washington University; Harold W. Arendes, methods engineering supervisor, American Steel Foundries; Jay Goldman, Washington University; Gerald H. Lumsden, superintendent of industrial engineering department, Dow Chemical Co.; and Owen W. Miller, Washington University.

Because of the overflow classes in previous years, the course enrollment will be limited to the first 25 paid-up enrollees.

FACTS

about

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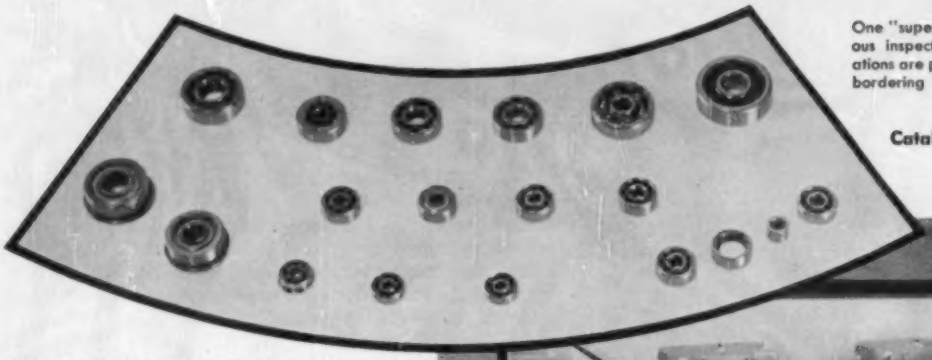

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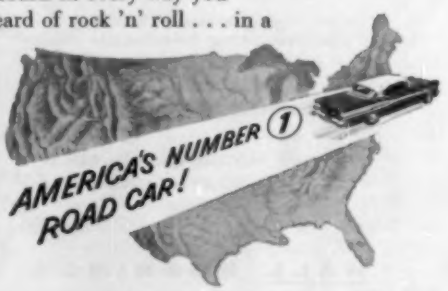

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Tuition for the course is $130, which includes textbook and workbook as well as all necessary supplies.

Further information on this course may be obtained by writing to Washington University, University College, St. Louis 5, Mo.

INTRODUCTORY QC SHORT COURSE Marquette University, in cooperation with the Milwaukee section of the Society, is offering a two-week short course entitled "Introduction to quality control by statistical methods" to be held June 10-21.

The program is designed for those in industry who desire a basic course in SQC and also for those who wish to apply the techniques to other managerial problem areas. Enrollees will be offered an opportunity to familiarize themselves with fundamentals, examine sample problems, become acquainted with the latest thinking and techniques in the field, broaden their concept of the use of statistical methods, and discuss common problems.

The staff for this course comprises Professor Gayle McElrath of the University of Minnesota and Harmon Bayer, quality control consultant, Detroit, Mich. They will be assisted by numerous guest speakers from industry.

Topics included in the course are basic techniques, basic charts, sampling, applying, and controlling.

The course fee will be $180.00 which includes all materials and ten lunches. Registration or further information may be obtained from Dr. Russell L. Moberly, Director, Management Center, College of Business Administration, Marquette University, Milwaukee 3, Wis.

PURDUE UNIVERSITY ADVANCED COURSE JUNE 11-21 The eleventh annual advanced course in "Quality control by statistical methods" will be held at Purdue University, Lafayette, Ind., June 11-21. The course is planned for those who have already had an elementary course and wish to go on to more advanced techniques.

The subject matter includes significance tests and estimation, acceptance sampling by variables, sequential analysis, linear and multiple correlation, and a thorough grounding in analysis of variance. There are 23 hour-sessions on the last subject and related topics. The course is under the direction of Professor Irving W. Burr of Purdue. It is expected that other instructors in the course will include Professors Cecil C. Craig of University of Michigan, Charles R. Hicks of Purdue, Lloyd A. Knowler of University of Iowa, Edwin G. Olds of Carnegie Institute of Technology, and Mason E. Wescott of Rutgers University.

Further information may be obtained from Professor Burr at Purdue University, Lafayette, Indiana.

ASME JUNE 9-14 Jet-age aircraft, atomic power, safer industrial machines, new gas turbine engines, air pollution control, and improved mechanization and efficiency in a half-dozen industries will be among the topics covered when the American Society of Mechanical Engineers hold their Semi-Annual Meeting on June 9-14, in San Francisco.

More than 130 papers written by experts in fields ranging from aviation to wood industries will be presented and discussed.

Those attending the meeting will tour industrial installations in the area, including the United Airlines Maintenance Base, the San Francisco Naval Shipyard, the General Electric atomic laboratory at Pleasanton, and the Aerojet General plant at Sacramento.

Further information is available from ASME, 29 West 39th St., New York 18, N. Y.

CORNELL UNIVERSITY JUNE 11-14 On June 11-14, Cornell University will offer the fourth annual Industrial Engineering seminars. These seminars provide, in the congenial surroundings of a university campus, an opportunity for a critical study and reappraisal of some of the major problems in areas of interest to industrial management. Sessions are conducted to emphasize and encourage participation by members of each seminar group.

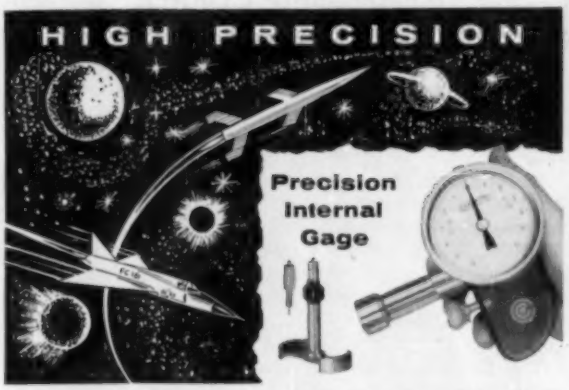
There will be ten seminar workshop sessions led by qualified discussion leaders in each of six major areas of industrial engineering—industrial management, manufacturing engineering, small plant management, methods and work measurement, applied industrial statistics, and data processing systems.

The fee for the course is $120 per person and includes notebooks, printed materials, two luncheons, a fellowship hour, banquet, and a barbecue.

Further information is available by writing to R. E. McGarrah, Seminars Coordinator, College of Engineering, Cornell University, Ithaca, N. Y.

"FOR MANY ARE CALLED, BUT FEW ARE . . ."

DELAWARE In the recent annual election the following officers were chosen to serve for the 1957-58 season: chairman—Hillman C. Harris; vice



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chairman—Edmund L. Niedzielski; secretary—Francis Holden; treasurer—Loren J. Steinhauer. Our congratulations to these men and our pledge of full support and cooperation throughout the coming season.

HAMILTON -MIDDLETOWN W. G. Thompson of the Champion Paper and Fiber Co. has been elected to chairman to replace Keith Sherck who has been transferred by his company.

LOS ANGELES The following were elected as officers of the section for the 1957-58 year. Chairman—Dr. Leo A. Aroian, Head, Math Sec., Systems Analysis Dept., Hughes Aircraft Co.; vice chairman—Howard C. Todt, Chief, QC Analysis, Autonetics, a division of North American Aviation; and treasurer—Halmond L. Parks, Aerojet-General Corp.

MID-HUDSON The following officers were nominated and elected at the March meeting to serve for the year 1957-58: John Losee, De Laval Separotor Co., chairman; Davis Gale, Triangle Electronics Mfg. Co., vice chairman; William Cranston, Western Printing and Lithographing Co., treasurer; Casper Rose, De Laval Separator Co., permanent secretary.

SOUTH BEND -MISHAWAKA The new officers for the coming season are: chairman—Wayne Miller, Bendix Products; vice chairman—Charles Makowsky, Bendix Products; secretary—Paul Boynton, Bendix Products; and treasurer—Fred De Vries, Ivano, Inc.

MEMBERSHIP CORNER

To: Industrial Quality Control
SUBJECT: Membership Growth
REFERENCE: Mr. L. S. Eichelberger's Membership Report of March 7, 1957

According to the last membership report for February 24, 1957, our Section (Harrisburg) now stands at 190 percent of the membership officially recorded as of June 30, 1956. This was not a simple task as any membership chairman will agree. However, a breakdown of where this increase of membership was found might be of use to other sections in realizing our future membership goals.

The Harrisburg Section covers in principle the area including Harrisburg, York, and Lancaster. Within these three cities are a great many companies both large and small. These are very diversified in nature, insofar as type of operation and product are concerned. Hence, we have a compatible setup to the promotion of interest in Quality Control which results in the natural growth of potential members. This in itself is by no means the answer to increased membership, but serves as a sound base upon which we can operate.

Let's break down our current membership and see where it comes from. Of the reported 135 members

1. Approximately 50 renewed prior membership.
2. Approximately 50 new members were g a i n e d through local courses in quality control.
3. Approximately 35 new members were s e c u r e d through other sources (actually this figure is now somewhat higher due to in-process membership applications received.)

Two years ago we realized that our membership renewal rate was not all it was cracked up to be and we had better get "on the ball" if we were to survive. Actually, although this year our rate was only 71 percent, it represents a group which are active and who will have a very high rate year after year.

The largest bulk of increased membership was realized through two basic and one advanced course in statistical quality control supervised and taught by members of the Harrisburg Section. Each non-member attending one of these courses was required to pay a fee large enough to cover both operating expenses and a membership in ASQC. Actually, courses were completed by 61 people. Our problem of the future is to hold this new membership. We expect to do this with new advanced courses next year as well as a sound meeting program.

A large portion of the total membership was secured through other sources than the above. The responsibility for this achievement as well as the above can only be attributed to our membership as a whole. Everyone has done an excellent job in promoting section growth. This job is a continuing one as evidenced by the fact that our March meeting found a member attending with 40 of his co-workers all interested in quality control. Such interest in the Society can only result in growth.

To sum up our performance record it was only realized by the complete cooperation of the membership and to quote the title of a book by Sir Winston Churchill, *"Blood, Sweat and Tears."*

S. A. Combs
Membership Chairman, Harrisburg Section

DIVISIONS

Brewing Technical Committee

The Executive Committee of the Society has approved the elevation of the Brewing Steering Committee to the

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Technical Committee status. The officers who will direct the activity of the Brewing Technical Committee are:

Chairman: John S. Randall, Anheuser-Busch, Inc., St. Louis, Mo.

Vice-Chairman: Robert I. Tenney, Wahl-Henius Institute, Chicago, Ill.

Secretary: William H. Von Meyer, Barry-Wehmiller Machinery Co., St. Louis, Mo.

Treasurer: G. Calvin Dyson, G. Schmidt & Sons, Inc., Philadelphia, Pa.

The first official meeting of the Technical Committee was held in Milwaukee, Wisconsin on March 14, 1957 in conjunction with the Milwaukee Industrial Clinic for Quality Control. The meeting was attended by 21 members who expressed interest in the activity of the Committee. During the meeting a Task Group was formally established to survey the applications of Statistical Quality Control in the Brewing Industry. This survey will not only encompass the applications in Brewing, but will also include the suppliers to the industry.

The basic objective of the Brewing Technical Committee shall be to foster the use of the principles and techniques of Statistical Quality Control in the brewing industry. Information regarding membership in the Brewing Technical Committee can be obtained from the Membership Chairman: Mr. Otto C. Lucht, Manager of Quality Control, Froedtert Malt Corp., Milwaukee, Wis.

CORRECTION NOTICE

Several typographical errors occured in Clyde Y. Kramer's article, "Simplified Computations for Multiple Regression," which appeared in the February, 1957 issue of *Industrial Quality Control.*

On page 8, column two, the equation for a_{ty} should read

$$a_{ty} = \sum_{a=1}^{n} x_{ta} y_a - \frac{\left(\sum_{a=1}^{n} x_{ta}\right)\left(\sum_{a=1}^{n} y_a\right)}{n} ,$$

On page 10, column one, equations (7) and (8) should read

$$(7) \qquad F = \frac{10^{-2p} A_{1y} B_{1y}}{\frac{(a_{yy} - 10^{-2p} A_{1y} B_{1y})}{n-2}}$$

$$(8) \qquad F = \frac{10^{-2p} A_{3y} B_{3y}}{\frac{(a_{yy} - 10^{-2p} \sum_{i=1}^{3} A_{iy} B_{iy})}{n-4}}$$

Our apologies to Mr. Kramer and our readers.

SIGNIFICANT DIFFERENCES

Allentown-Bethlehem section chairman Doug Adams has been promoted to department chief, quality control, at the Fullerton Avenue Shops of Western Electric's Hawthorne Works in Chicago.

Stanley T. Updyke, Corning-Elmira section, recently received a "managerial award" from the General Electric Co. for his outstanding work in substituting for the manager of marketing at the G. E. Plant in Elmira, N. Y., for five months.

Georgia section member Harry O. Fewox, formerly staff statistician of the Southern Bell Telephone & Telegraph Co., has been promoted to general statistician, where he will have an opportunity to apply statistical methods in the solutions of more problems.

Kenneth H. Bitting, Jr., has transferred from the St. Louis section to the Los Angeles section. Mr. Bitting is associated with the Anheuser-Busch Co. and serves as an assistant general manager of its Los Angeles brewery.

Dean Voegtlen, engineer on the quality director's staff at Hughes Aircraft, has accepted a position with RCA as manager of reliability research projects. He will be stationed at Rome Air Development Center, Rome, N. Y. The Los Angeles section will certainly miss him as he has been quite active in reliability programs.

Irv. Schoeninger, past president of the Milwaukee section, was recently cited in Scanfax, a section publication of the Institute of Radio Engineers, in a short article describing his contributions to ASQC. Of especial interest was the publicity given his book, *Quality Control as an Aid to Engineering Management.*

Dr. Joseph V. Talacko, senior member of the Milwaukee section, was elected president of the Milwaukee Chapter of the American Statistical Association.

Recent organizational changes made at the Boeing Airplane Co. affected several members of the Seattle

Look to

MSD

For New Advances in Medical Science

On August 1, 1956, Sharp & Dohme, the pharmaceutical and biological division of Merck & Co., Inc. became "Merck Sharp & Dohme" to reflect the teamwork which has produced significant new medical products.

Merck Sharp & Dohme—combining in name as well as in fact the traditions and experience of two time-honored leaders in the medicinal field—offers bright promise for further advances in medical science.

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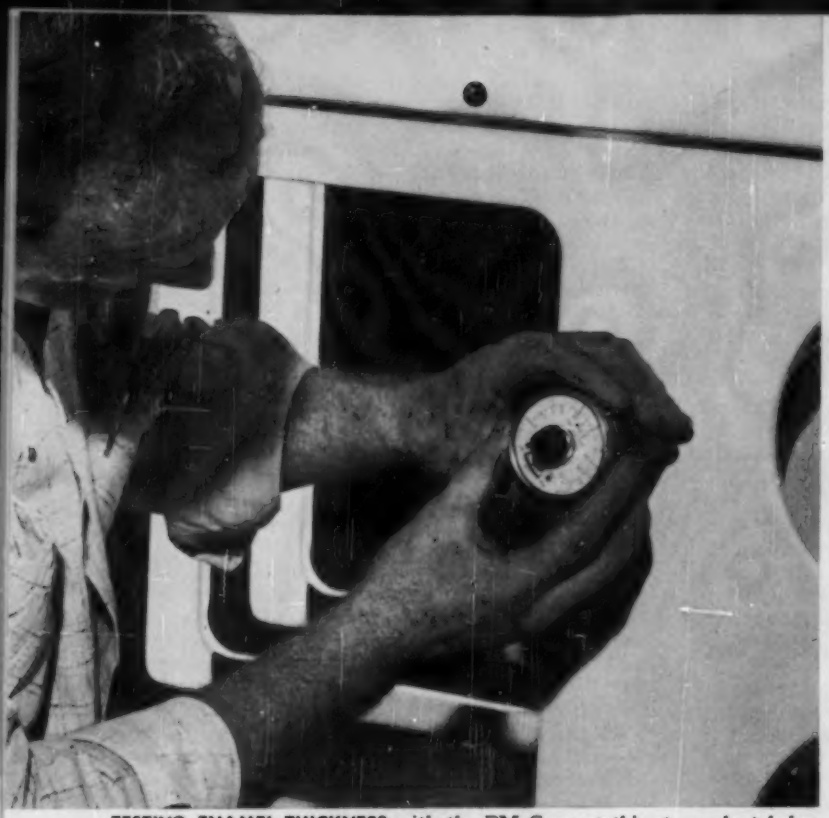
Division of Merck & Co., Inc.



TESTING ENAMEL THICKNESS with the PM Gage at this stove plant helps assure quality production.

NEW G-E Thickness Gage Gives Faster Product Inspection

General Electric's new permanent magnet thickness gage speeds production testing and helps assure you quality production and savings in materials. It is portable, self-contained and small enough to hold in your hand.

The new gage gives non-destructive thickness measurements of non-magnetic coatings, such as paint or plating, on magnetic iron or steel. Other non-magnetic materials—plastic, celluloid, mica, and paper—can also be measured when placed on a smooth, magnetic plate.

Dual-Range Scales of 0 to 7 mils and 1 to 60 mils are expanded at the lower end to give you greater readability.

"Go—not-go" Pointers simplify testing for production quality control.

Self-contained, the PM Gage requires no external power. An Alnico magnet furnishes the necessary flux.

For further information on the PM thickness gage contact your nearest G-E Apparatus sales office, or write for bulletin GEA-6458 to Section 585-51, General Electric Company, Schenectady 5, New York.

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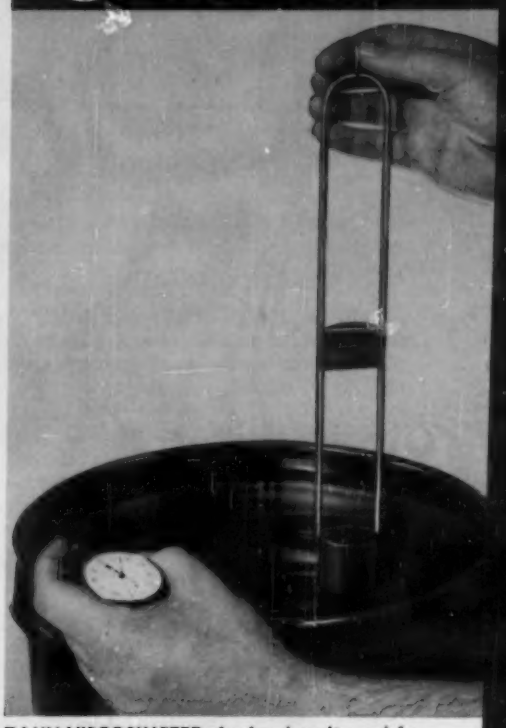
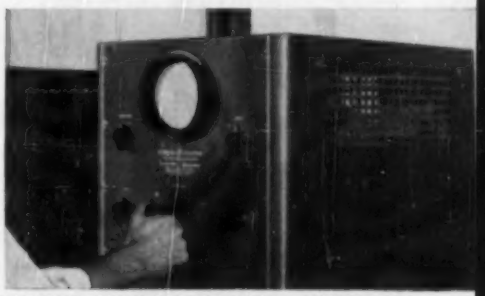
INSTRUMENTS FOR QUALITY CONTROL



ZAHN VISCOSIMETER checks viscosity quickly and easily—in 20 to 40 seconds. Temperature and time of flow are measured in one simple operation. Maintain quality of liquids and painted surfaces. Bulletin GEC-339.

SURFACE ROUGHNESS SCALES and specimens provide time and cost saving standards for machined surfaces. Degree of roughness can be specified on drawings and checked by machinist as he works. Bulletin GEC-774.



WINDING INSULATION TESTER quickly tests for both insulation faults and winding dissymmetries in motors etc. Tests at surge peak voltages up to 10,000 volts. Does not harm insulation. Bulletin GEC-321.

section. Those affected and their new assignments are: Cecil Houchen, supervisor of QC engineering, transport division; Carroll S. Olson, chief of QC staff, transport division; Ralph Thomas, chief of QC staff, Seattle division; Gordon Siddens, supervisor of QC engineering, Seattle division; and Curtis H. Birge, QC manager, pilotless aircraft division.

Atlas Powder Co. has announced the appointment of Joseph S. Rhodes, Cleveland section, as manager of operations research, a new post in its economic evaluation department.

Ralph A. Maggio, Pittsburgh section, has been named a staff statistician for Jones & Laughlin Steel Corp. His post is in the applied mathematics group of the research and development department.

Cincinnati section member M. J. Bratt spoke on Mar. 26 at the Western States Convention of the Society for Non-Destructive Testing at Los Angeles on "Uses of statistical methods for ultrasonic inspection." Another member, Vernon Wiegan, served as a moderator at this same convention.

The appointment of John Ca[illegible], a member of the Corning-Elmira section, to a new position as quality control manager of the new Greenville, Ohio plant of Corning Glass Works has been announced.

Keith Sherck has been promoted to quality control manager at Pillsbury Mills, Springfield, Ill. Marvin Byer succeeds Mr. Scherck as quality control manager at Pillsbury Mills, Hamilton, Ohio. Mr. Scherck has been a very active member of the Cincinnati section and was chairman of the recently established Hamilton-Middletown section.

Wayne M. Biklen, Director of Quality Control for American Safety Razor Corp. since 1953, now wears two hats for this company, having been appointed, effective March 1, 1957, Director of Engineering in addition to retaining his divisional quality control responsibilities. Wayne, formerly with the W. A. Sheaffer Pen Company at Fort Madison, Iowa, is a Fellow of ASQC, and a Past Chairman of the State University of Iowa Section, ASQC.

In the past two years Wayne has also been a veritable work horse as a speaker on various aspects of the theme that SQC is a fundamental and indispensable tool of good, modern management. He addressed the American Management Association's Special Manufacturing Conference on Reducing Costs with a discussion of "Quality Control's Contribution to the Reduction of Manufacturing Costs". He has twice chairmanned the five-day Annual AMA Workshop Seminar on "Administration of the Quality Control Function." He was guest lecturer at AMA's Annual Orientation Seminar on "Organization of Quality Control Function," and a speaker at the AMA Annual Manufacturing Conference on "What Top Management Should Expect from Quality Control." He has also served as a speaker on programs of the International Method-Time-Measurement M.T.M. Conference, the Society for Advancement of Management, ASQC, and other technical associations on SQC subjects such as "Can Quality and Incentives Live Together," and "Incentives, Piece Work, and Quality."

In one stretch of ten months he met thirteen speaking engagements in the interest of promoting a better understanding of SQC principles and practice at Top Management levels. This record bids well to put Wayne in the same class with Hugo Weisbrodt, often affectionately known in an earlier era of ASQC as "the Billy Sunday of SQC".

The Society suffered a great loss when Ervin E. Schiesel, Vice President of ASQC and President of Arrowhead Associates, was killed in an automobile accident near Meriden, Conn. on April 16.

What's New?

ROY A. WYLIE, *Editor*

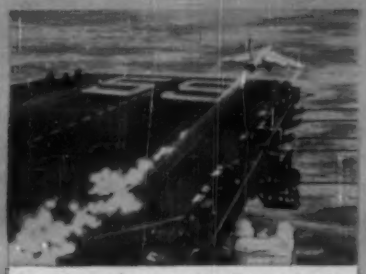
When inquiring about "What's New?" items, please mention INDUSTRIAL QUALITY CONTROL

"While-you-wait" x-rays are possible with new equipment developed by the **General Electric Co., X-Ray Department,** Milwaukee 1, Wis. This new "less-than-a-minute" x-ray processing system features a dry, electrostatic system in which the x-ray image is produced by a dry powder on a sensitive metal plate. The process is known as zero-radiography and permits an image-developing procedure that takes less than one minute to complete. There is no need for cumbersome, wet-chemical methods of developing a film in an enclosed dark room. Instead, the exposed zeroradiagraphic plate is inserted into a "dusting" chamber, where chalky powder is sprayed against its surface. Where the electrical charge is greatest, the powder clings in greater quantity, converting an invisible electrical image into a visible picture. The image can then be erased and the plate re-used, providing what is termed "blackboard" x-ray. Because it speeds processing so that production is not delayed and because plate re-usability drastically cuts image costs, zeroradiography will make possible widespread use of 100 percent inspection of products by industry. Provision is also made for securing a paper copy of the zeroradiographic image, thus providing a permanent record of the image. The equipment is available for use with several models of industrial x-ray equipment manufactured by General Electric X-Ray Department.

* * *

Phoenix Precision Instrument Co., 3803-05 North Fifth St., Philadelphia 40, Pa., announces a new Automatic Process Refractometer for end point analysis and control in the Chemical, Petroleum, Pharmaceutical, and Food Processing fields. The instrument is able to plot refractive index changes in any non-opaque liquid or gas stream. A few of the many applications include: checking and controlling product purity; measuring and controlling the blending of two streams; measuring and controlling concentrations of gases and solids in solutions; identifying compounds as they are released from fractionators, stills, and chromatographic columns. The instrument can be supplied to meet Class 1 Group D requirements for hazardous locations. The instru-

Catapult Officer gives the signal, and the Vought F8U-1 *Crusader* is hurtled along the deck by the Forrestal's steam catapult...



...airborne in a matter of seconds, the *Crusader* streaks skyward at a speed never before attained by a Navy jet fighter...

...while below, the mighty Forrestal's size and speed dramatize the devastating long-range striking power of the New Air Navy.

1000 + mph *Crusader* qualifies aboard ship!

SPECIAL: WITH THE USS FORRESTAL AT SEA. Aviation history was made aboard this new attack carrier when the flashing Chance Vought F8U-1 *Crusader* successfully completed its shipboard qualification trials.

The trials, held off the Atlantic Coast, marked the first time that an aircraft capable of level flight speeds in excess of 1,000 miles an hour had ever operated from a carrier deck.

Designed and built by Chance Vought, the *Crusader* met all of the Navy's stringent shipboard operating requirements like a champion. This blazing new air superiority fighter soon will be assigned to active duty with the Fleet, adding 1,000 miles-an-hour-plus performance to the growing strength of America's Defense Team.

Scientists and Engineers: There is a challenging place for you on Vought's creative team now. Write: J. W. Larson, Assistant Chief Engineer, P. O. Box 5907, Dallas, Texas.

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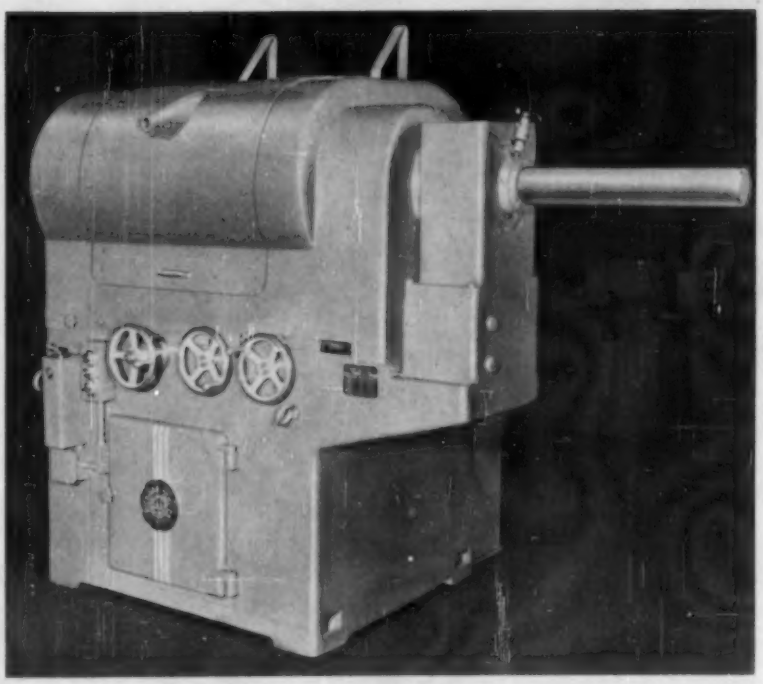
ment is the null type, and is designed for continuous operation on any 115 volt single phase 60 cycle AC line. No batteries are required.

★ ★ ★

The **Marsh Stencil Machine Co.**, Belleville, Ill., is now marketing a new squeeze bottle Felt-Point Marker that controls the flow of ink with a squeeze bottle. The new product, especially suited for control chart work, is called SQUEEZO Marker. It holds ¾ ounce of water color ink and sells for 79¢ in stores. The new water ink is for porous surface marking and does not "strike thru" even the cheapest grade of news-print chart paper. Eight bright colors make multiple color chart work easy. Marsh Company claims there is over one mile of ⅛ inch wide mark in each SQUEEZO. Ink comes off hands with a little soap and water.

★ ★ ★

Easier and truer noise inspection of larger size mating gears is possible with a modified standard gear speeder from **Michigan Tool Co.**, 7171 East McNichols Road, Detroit 12, Mich. The Model 1129-SP uses enclosed spindles and a special built-in listening horn for better definition of noise characteristics for



this particular application. The machine can be provided with fittings for contact microphones and other acoustical equipment. In operation, only one spindle is driven with brake loads applied to the opposite spindle. The driven spindle is reversible. Four spindle speeds (580, 870, 1160 and 1740 RPM) are obtained from a four-speed constant-torque ¾ hp motor. The external contact friction brakes are manually

Where ***LIVES depend on quality control***

In pharmaceuticals, as in nothing else, too much of a good thing—or too little—can be disastrous. With few exceptions, a drug's potential for good is directly matched by its potential for harm in the event of misuse or error.

In the manufacture of antibiotics and specialized pharmaceuticals, Bristol Laboratories enforces a rigid system of checks and counter-checks at every step—from the receiving platform to the shipping room—to assure unvarying consonance of composition with label specifications on each of its many products. There can be no compromise—a human life may depend on it.

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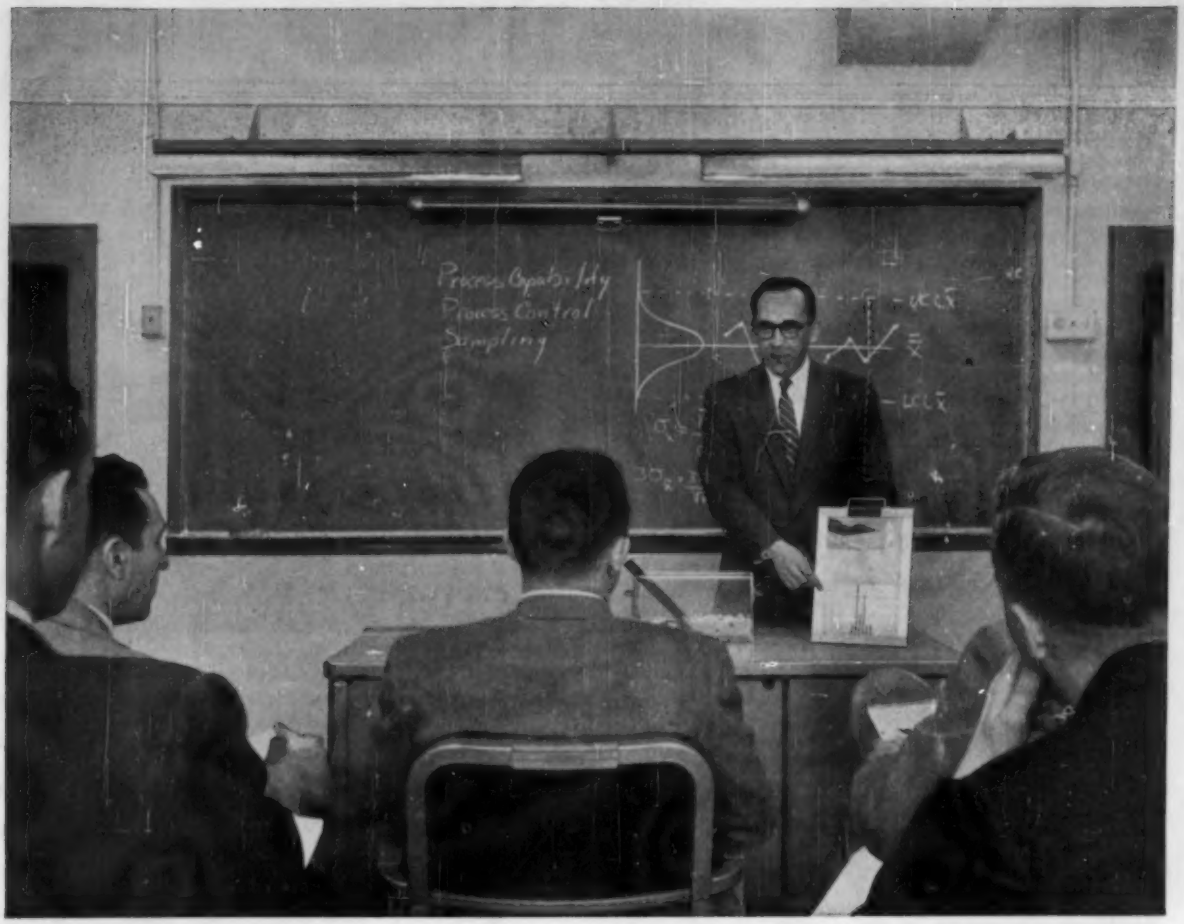


An essential aspect of SQC in Western Electric

We of Western Electric are sold on Statistical Quality Control — so much that we have continuously maintained a training program to bring it home to our employees.

In all of our manufacturing locations, classes such as the one shown above give people in all levels of management a deeper appreciation of SQC and its many values and uses. Our shop people, too, are instructed in the aspects of quality control which relate to their jobs and help them build quality into our products.

We have been a pioneer in SQC and an extensive user of it for over a quarter of a century. From the wiring of small switchboard components to the vast and complex extrusion presses which sheath heavy telephone cable in metal and plastic, we have been using the most advanced quality control methods.

Indeed, SQC is one of the important factors that helps to achieve the Bell System goal . . . good, dependable telephone service at low cost.

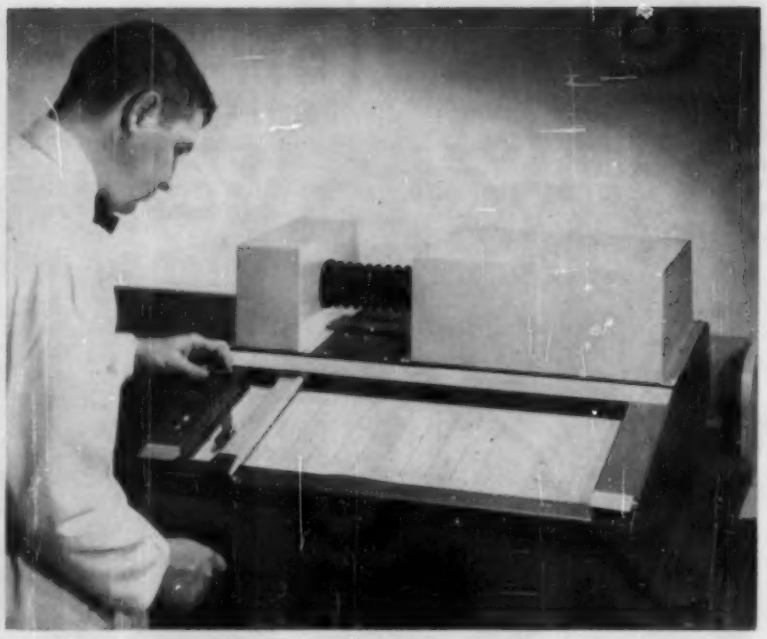
Western Electric

MANUFACTURING AND SUPPLY UNIT OF THE BELL SYSTEM

operated and accommodate a variable load. The speed will accept gears up to a maximum diameter of 23 inches with a maximum face width of 10 inches. Center distance range is 2½ to 12 inches. Distance between centers on front and rear spindles in 25 inches. Floor space requirements are 46½ × 99 inches.

★ ★ ★

The Scientific Instruments Division of **Beckman Instruments, Inc.**, 2500 Fullerton Road, Fullerton, Calif., announces the development of a new type of infrared spectrophotometer. The new instrument—the BECKMAN IR-6—records linearly in transmittance and wave-length from 2 to 16 microns, and offers excellent accuracy and resolution for qualitative and quantitative analysis. The instrument sells for less than $5,000—about one-third the price of the larger infrared spectraphotometers. The IR-6 was designed by Dr. John U. White and his associates of the White Development Corp. Dr. White is well-known for his contributions to infrared spectoscopy and instrumentation. Pushing a single button will start a 16-minute scan through the entire 2-16 micron spectrum. More than a score of accessories are



available for special measurement application, including accessories for the sampling of solids, liquids and gases, for misco-samples and for reflectance. The IR-6 features a flat-bed recorder which shows the entire spectrum traced on pre-printed, file-size charts. The simple electronics and optics are housed, together with the recorder, in a single compact console, 30 inches long, 25 inches wide, and 14 inches high. The unit weighs about 100 pounds.

★ ★ ★

A non-destructive, very high potential unit is now available for insulation testing of samples, or full reel tank testing. The unit offers a method of checking the insulation of cables that meets new IPCEA standards as well as MIL, JAN and ASTM specifications. Many of the features incorporated in the unit are:

- 0-100 KV voltage output
- Adequate capacity for rapidly charging full reels
- Automatic Output shorting
- External interlock provision
- KV meter and current meter for determining leakage resistance
- Overcurrent trip-out to deenergize HV
- Dual range meters

The unit incorporates all the safety and convenience features of other sets. Further information can be obtained from the manufacturer, **Peschel Electronics Inc.**, 19 Garden St., New Rochelle, N. Y.

★ ★ ★

Allen B. DuMont Laboratories, Inc., 750 Bloomfield Ave., Clifton, New Jersey, has developed a vacuum-tube

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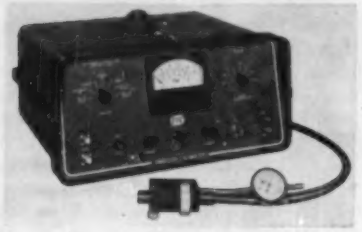
voltmeter that combines 100 millivolt full scale sensitivity with dual and differential input features. The instrument features a d-c performance from two millivolts to 1,000 volts with 121 megohms input resistance. A-c performance is accurate from below 50 cycles per second to ultra-high frequencies. As an ohmeter, the scale of the Type 405 is calibrated from zero to 500 with eight multiplier ranges—X1 to X10 meg. The type 405 is functionally designed to reduce fatigue factors, reading difficulties, and other human accuracy deterrents associated with electronic instrumentation. A nine-position switch on the front panel allows dc-voltage measurements through calibrated ranges from 100 millivolts full-scale to 1000 volts full-scale. The 121 megohms input resistance for these measurements virtually eliminates loading of the circuits being measured. The Type 405 is housed in a compact cabinet with provision for using the instrument in an upright position or flat on its back. At the bottom of the cabinet is a compartment for storing the probes when not in use. The unit weighs just 12 pounds.

★ ★ ★

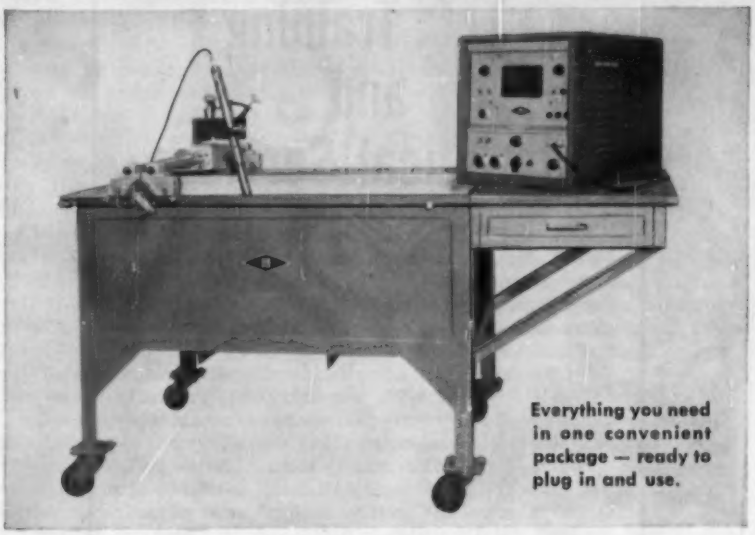


A new type of Vibration Calibrator utilizing a non-contacting probe and capable of measuring vibrations of from 10 to 20,000 cps with amplitudes of 20 to 20,000 micro-inches, has been announced by **Tel-Instrument Electronics Corp.**, Carlstadt, N. J. The TIC, Model 501 unit is designed to measure with an accuracy of ±5 percent, vibration amplitudes of non-magnetic metals such as copper, brass and aluminum while utilizing a minimum surface diameter of ⅞-inch. Model 501 may also be used on magnetic metals like iron and steel, as well as on non-metallic surfaces, by cementing a piece of copper or aluminum foil 0.01 inches thick and 1 inch in diameter to the surface under the transducer. The Model 501 utilizes a method of comparing peak-to-peak displacement of a vibrating surface with a standard displacement allowing direct reading, in thousandths of an inch, of the variation in output produced by the vibrating surface. Since no surface contact is required, there is no "loading" of the vibrating surface, further assuring specified accuracy of the unit. An attenuator provides ranges of 0.02, 0.06, 0.2, 0.6, 2.0, 6.0, and 20.0 thousandths of an inch, with the same ±5 percent accuracy attainable over all ranges. The unit weighs 30 pounds and is equipped with a handle for carrying. Binding posts are provided to permit observation of vibration waveforms on a conventional oscilloscope.

★ ★ ★

The Telescopic Alignment Kit for use by airframe manufacturers with its standard Model PD-150 closed-circuit television system has been developed by **General Precision Laboratory Inc.**, Pleasantville, N. Y. The Kit increases efficiency and accuracy in tooling problems calling

ULTRASONIC INSPECTION



Everything you need in one convenient package — ready to plug in and use.

COMPLETE, THRIFTY PACKAGE
for immersed nondestructive testing

Now Curtiss-Wright offers all the benefits of immersion ultrasonic testing of metal without the expense of an assembly of several costly separate units. This new low cost "package" combines in a self-contained single unit the Immerscope — the heart of the system — a four-foot tank, search tube and rack, precision manual manipulator, longitudinal and transverse manual scanning mechanism and a complement of crystals. Here is a complete immersion testing, quality control installation ready to operate, whether in laboratory or light production — a system that can be readily expanded, with only minor investment, for more demanding production applications.

The technique is simple. Metal parts are immersed in water. Ultrasound is applied to penetrate the metal. Defects present will reflect the sound. Those echoes are presented as pips on the cathode ray tube of the Immerscope. Flaw detection is precise and positive.

Complete information on request. Our local representative is available to discuss your problem.

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for precision optical alignment by substituting precise visual communication for less certain verbal or hand direction previously used. With the TV camera taking the place of an observer behind the telescope, cross-hairs in each frame are lined up with a light source cross-hair by watching the pictures appearing on the monitor screen. This permits one man to handle tasks involving extremely close tolerances such as the alignment of aircraft fuselage or wing frames. The wheel-mounted monitor can be moved from frame to frame as necessary. Additional cameras and alignment kits are used when the application requires more than one set of cross-hairs for establishing a definite plane. With GPL's camera switcher, the aligner can make instantaneous reference to any one of the cameras by pushing the selector button of the desired camera. The new GPL Telescopic Alignment Kit is used with most telescopes conforming to AIA standards and is adaptable to others with different barrel diameters.

* * *

The **EAM Division, Industrial Gauges Corp.**, West Englewood, N. J. offers for prompt delivery a sorting machine that will sort anything from bearing balls to gears and piston pins into as many as thirteen categories. The "Autosorter" is based on a new no-drift electronic principle of gauging plus a simple mechanical memory system. The same machine can be used for increments anywhere from ten millionths to ten thousandths. Accuracy between classes is guaranteed as low as 0.000002 inches, the speed range averages around 10,000 pieces per hour, depending upon the size and type of the piece. For changing to different types of work pieces, the top portion containing the mechanical feeding and positioning elements is removed and replaced in 5–10 minutes by means of three cap screws. For visual inspection of balls and rollers, a stroboscopic light in window indi-

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An excellent position is immediately available in New York City with a medium size company engaged for over forty years in research, engineering development, and manufacture of complex electronic, electro mechanical or mechanical control and computer systems.

To fill this position the candidate must have a bachelor's degree with some engineering background plus at least one year post graduate studies in mathematics and seven years of employment by industry in statistical quality control methods. He will serve the Engineering Division as well as the Quality Control Division in the application of modern statistical methods to problems of product design and testing. He will train company personnel in effective statistical quality control procedures, plan statistical techniques and procedures for inspection and testing, conduct special statistical investigations and improve Q.C. services. Must be a U.S. citizen capable of obtaining security clearance. The opportunities and benefits with our company are many.

Your replies will be kept in strict confidence. Kindly send complete resume and be specific about the salary at which you will expect to start.

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cates out of roundness. The equipment is compact and portable.

★ ★ ★

Clark Engineering and Manufacturing Co., 1820 Layard Ave., Racine, Wis. has announced a concentricity gauge which can be used in unlimited locations and positions, because it is attached magnetically. The unit can be used on drill presses, boring tools and lathes; in toolrooms, inspection and production operations. The lateral adjustment mechanism for the indicator is mounted in a permanently magnetized holder and the aluminum guide blocks are each set in a magnetized satin chrome base, complete with a padded wooden box. The gauge provides quick accurate set up for checking concentricity of shafts. The Clark Concentricity Gauge sells for $97.50.

★ ★ ★

Crystal Research Laboratories, Inc., 29 Allyn Street, Hartford 4, Conn. has introduced a new testing device called the Crystalab IONIMETER Model CT-21. The IONIMETER solves the problem of quickly and economically determining the quality of water used in exacting applications, such as are demanded in many laboratory and production practices. The unit comes equipped with a D'Arsonval meter with direct reading dial graduated 0 to 50 in parts per million as NaCl. The scale range converted into electrical resistance is 5,000,000 to 0 ohms. The price of the IONIMETER, Model CT-21 is $29.50.

★ ★ ★

Rate of pressure changes can be measured directly with a new SLM transducer system, Model PI-114 introduced by the **Kistler Instrument Corp.**, 15 Webster St., North Tonawanda, N. Y. Utilizing the "elec-

trostatic" principle, this rugged instrument permits precision rate or dynamic pressure measurements under the most severe conditions. Through the use of an adaptor and resistor element, the electrical current (rate of change of charge) generated in the Swiss-made quartz crystal transducer is measured by an "electrostatic" type amplifier and displayed on a standard oscilloscope or recorder. Because of the fast response (15 micro second rise time) and high sensitivity, this instrument is valuable for studying cylinder processes on engines and compressors. It may be used for indicating combustion and detonation phenomena in the evaluation of new engines and fuels. Other applications include shock tubes, gun tubes, rocket motors and hydraulic or pneumatic systems. The stainless steel pickup (transducer) is rugged enough to withstand diesel combustion and other temperatures up to 600 degrees F. without special air or water cooling. The amplifier-calibrator unit contains circuitry for calibration of the pickup, adjustment of the oscilloscope and the signal evaluation. Constant calibration, independent of temperature, is achieved by static means. An electrical charge placed on the amplifier input will remain for hours or even days. By simply switching the amplifier range, the SLM Indicator will perform equally well in the range of zero to psi, as in the range of zero to 1000 psi.

★ ★ ★

Boonton Radio Corp., Boonton, N. J., announces a new Film Gauge, type

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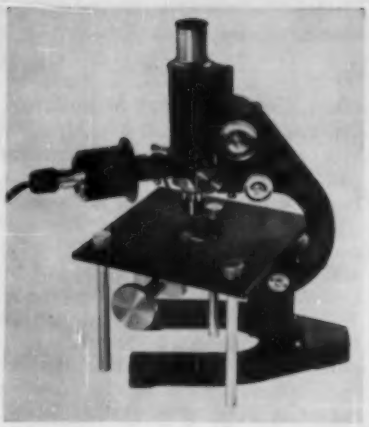
★ ★ ★

The Flinn Strain Viewer developed by Dr. Richard A. Flinn of the University of Michigan for microscopic examination of metals and other solids under stress is now being



produced by the **Harry W. Dietert Co.**, 9330 Roselawn Avenue, Detroit 4, Mich. The unit consists of a specimen table with a knife-edge loading device for the transverse loading of a miniature polished bar of material. The resulting plastic strain and mode of fracture can be viewed at all conventional magnifications including 1000 diameters. The specimen table is equipped with three legs for use with a bench type microscope and the legs may be removed if the table is to be placed directly on the stage of a metallurgical microscope. This device, when

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used with a suitable microscope, makes it possible to view and photograph not only fracture initiation and propagation, but also slip, twinning and phase transformations resulting from stress.

★ ★ ★

NEW LITERATURE

Ways to use low-cost optical instruments to simplify and speed manufacturing and inspection operations are outlined in a new booklet published by the Bausch & Lomb Optical Co., 635 St. Paul St., Rochester, N. Y. The booklet, "Industrial Optical Aids," contains up-to-date information on a wide assortment of inexpensive precision optical instruments and suggests ways to use them to gain faster, easier, lower-cost production. Items discussed include magnifiers, microscopes, wide field tubes, microscopes and comparators.

A new free price list of Atomic Energy Commission unclassified research reports for sale by the Office of Technical Services, U. S. Department of Commerce, is now available from OTS on request. This cumulative listing of the more than 3,600 AEC reports in the OTS collection contains 454 items acquired since June 30, 1956. To obtain the new list, request AEC Research Reports Price List No. 27 from OTS, U. S. Department of Commerce, Washington 25, D. C.

The Jarrell-Ash Co., 26 Farwell St., Newtonville 60, Mass. has made available a brochure representing the first of a series in spectrochemical reference hand books currently being prepared by Hilger & Watts, Ltd., British instrument manufacturer. This 28-page illustrated brochure describes the basic fundamentals of spectrochemical analysis, and includes a bibliography of reference material of value to spectrochemical analysis.

A new 16-page catalog of laboratory analytical instruments has been published by the Perkin - Elmer Corp., Norwalk, Conn. The catalog describes the company's line of infrared and ultraviolet spectrophotometers, monochromators, flame

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A S Q C Members. . . . .

We need your help in checking our records

The 1957-58 issue of the ASQC Membership Roster is now being prepared for publication this Fall.

If you have had any changes in your home address, company name or address, job title, or any other corrections that should be made, please fill out the blank at the left and return to National Headquarters at once.

Deadline for returning this form is **June 10, 1957.**

Mail to:
ASQC
161 W. Wisconsin Ave.
Milwaukee 3, Wis.

photometers, vapor fractometers, as well as accessories and instrument components available for use with them.

The Fischer and Porter Co., Hatboro, Pa. has just issued a new 16-page catalog describing its line of Lab-Crest glassware, fabricated from Pyrex brand glass.

OUR EVER-GROWING FAMILY

With the addition of Charleston (W. Va.), Hamilton-Middletown (Ohio), and Lima (Ohio), the number of sections in the Society is now 97. The Society is proud to extend a most cordial welcome to these new sections, and special congratulations to District Representative Ervin Taylor, who has the distinction of having all three sections in his district.

95—Charleston (Dist. 8)

Chairman: Robert M. Berg
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So. Charleston, W. Va.

Vice Chairman: Charles M. Drummond
E. I. du Pont de Nemours & Co., Inc.
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Charleston, W. Va.

Treasurer: H. C. Morton
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Hamilton, Ohio

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Lima, Ohio

Vice Chairman: Giles H. Howell
Baldwin Lima Hamilton Corp.
Lima, Ohio

Secretary: John Guernsey
Ex-Cell-O Corp.
Lima, Ohio

Treasurer: Martin Medow
Ford Motor Co.
Chicago, Ill.

POSITIONS AVAILABLE

Address all replies to box number references to: American Society for Quality Control, Room 6197 Plankinton Bldg., 161 W. Wisconsin Ave., Milwaukee, Wis.

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Responsibility of the American Society for Quality Control, Inc., for Consulting Services advertising is limited to certification that advertisers hold the grade of membership in the Society stated in their advertisements. Qualification requirements for the several grades of membership are set forth in the Constitution of the Society.

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Give full details of education, experience, desired salary, availability date and references. All inquiries will be considered promptly and held confidential.

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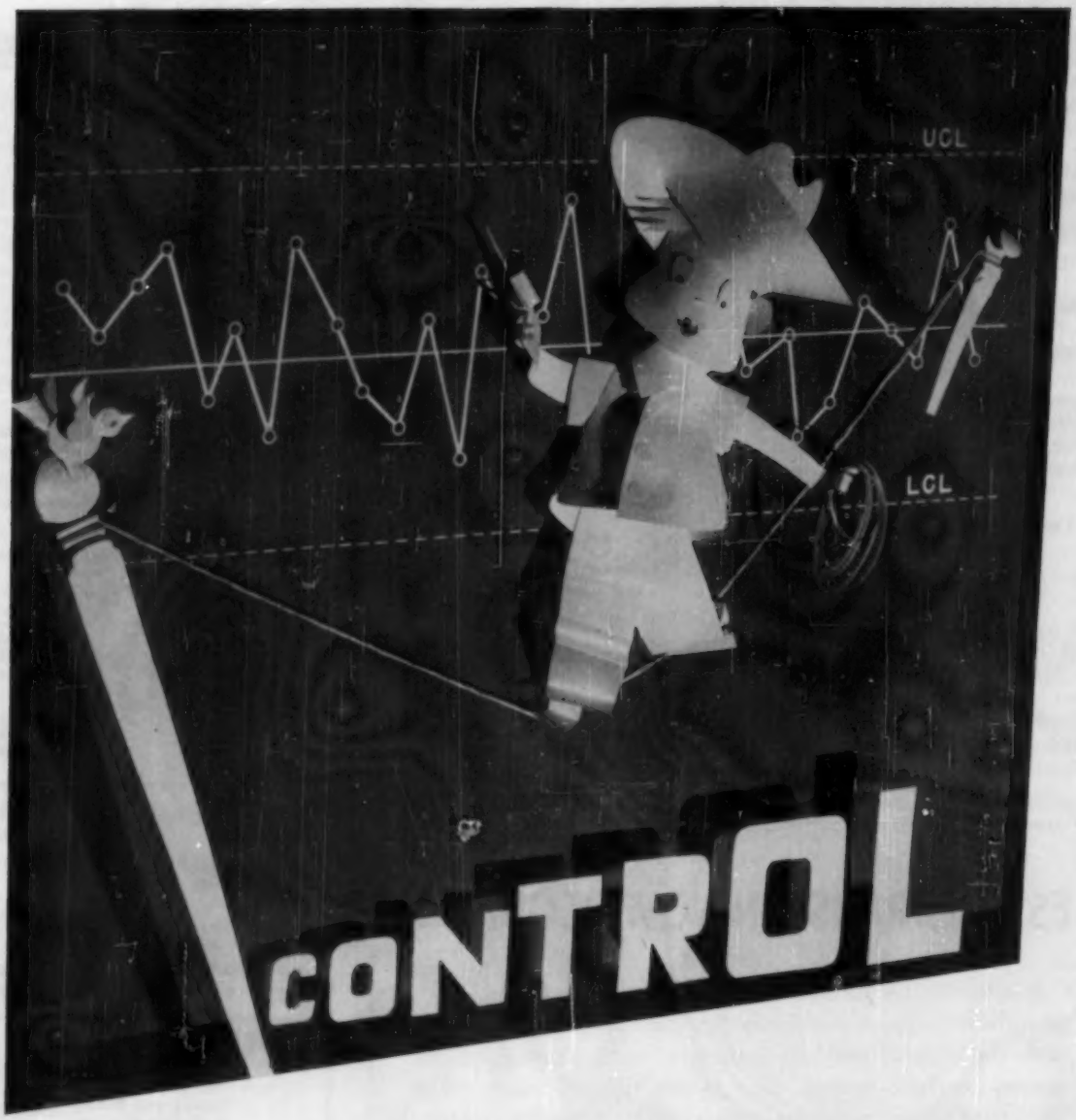

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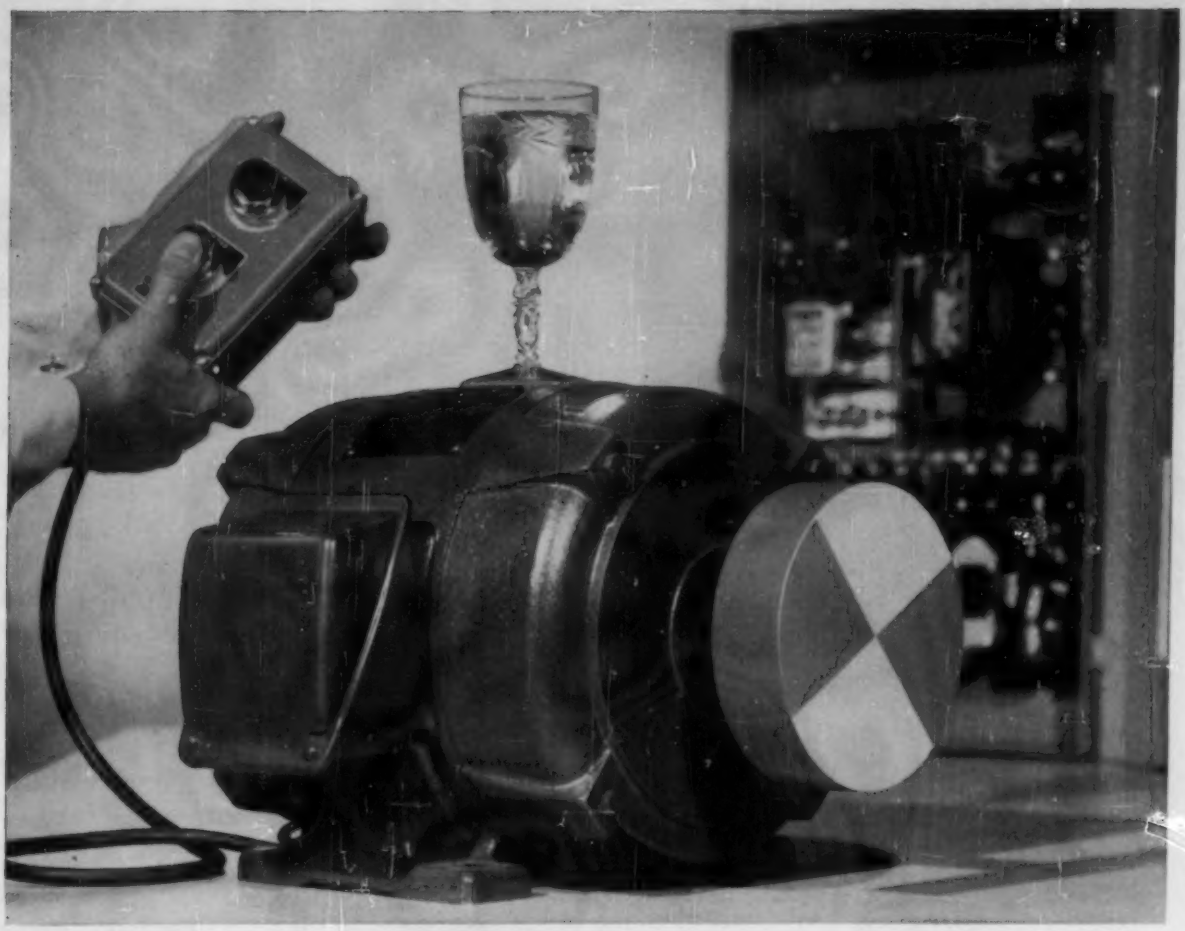

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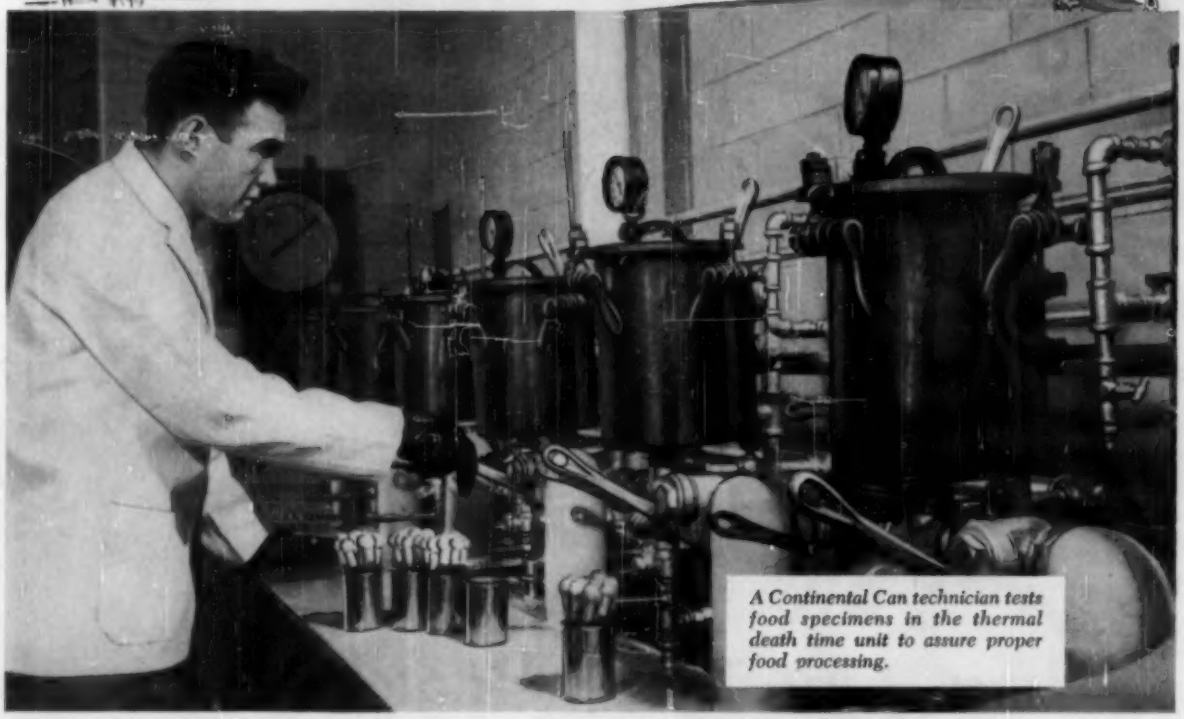
Research report from Continental



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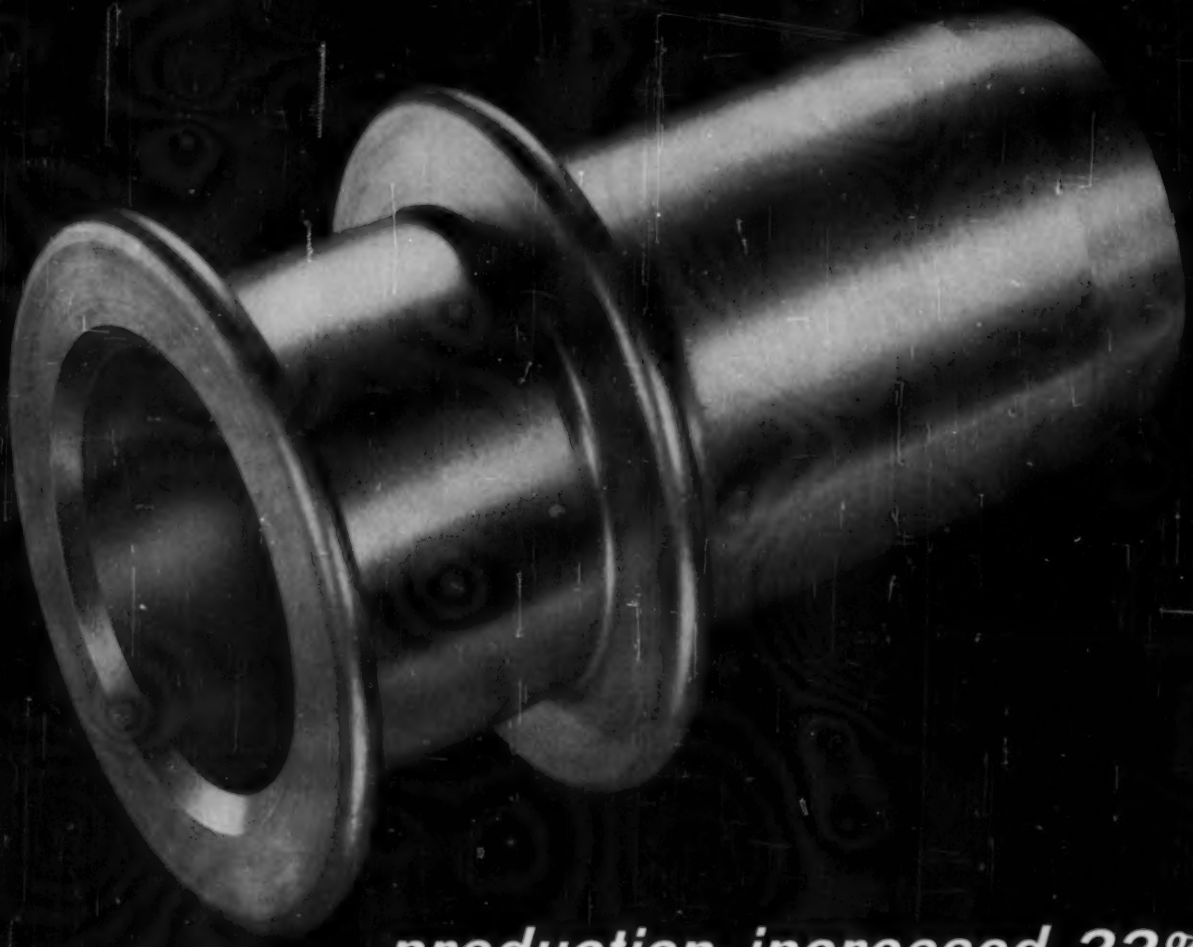

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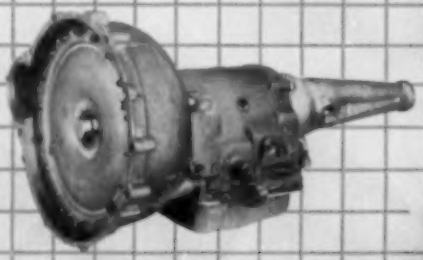

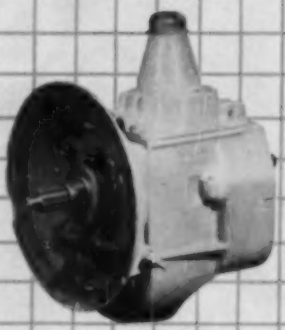

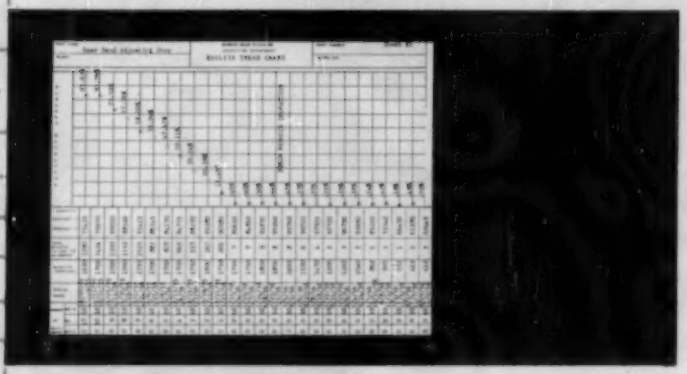

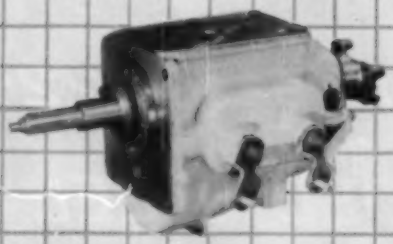

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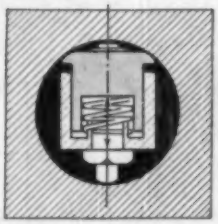

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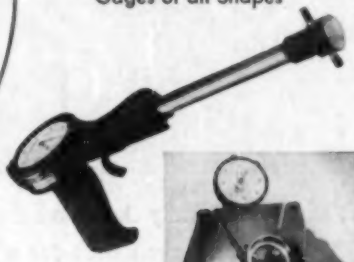

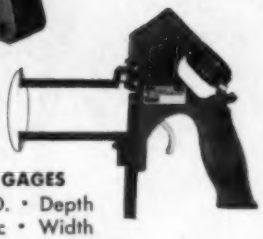

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